Table of Contents

Chapter		Page No.
1. INTRODUCTION		1-3
1.1	Need for renewable energy sources	1
1.2	Biogas: An appropriate energy technology	1
1.3	The manual: Objectives	2
1.4	Conspectus	3
2. BIOGAS TECHNOLOGY		4-20
2.1	Definition	4
2.2	Main components	4
2.3	Biogas Plant Models	9
2.31	Selection of a model	12
	a) Technical	
	b) Economic	
	c) Geographical	
	d) Climatic	
2.4	Advantages and limitations	13
2.5	Alternative technologies	16
3. BIOGAS TECHNOLOGY DEVELOPMENT PLAN		21-42
3.1	Introduction	21
3.2	Role of biogas technology	21
3.3	Policy formulation	26
3.4	Planning and programming	29
3.41	Organisational set up	29
	a) National Agency for Biogas Technology Development	30
	b) Regional Agency	30
	c) Microlevel Agencies	30
3.42	Plan formulation	31
3.421	Short term planning	31
3.422	Development plan	32
3.43	Phased out programme for development	33
3.5	Resources and demand assessment	33
3.51	Evaluation of resources	34
	i) Input materials	
	ii) Commercial energy sources	
	iii) Construction materials	
	iv) Accessary facilities	
	v) Ecology	
	vi) Geography	
	vii) Climatology	

Chapter		Page No.
3.52	Evaluation of energy needs and demand	37
	i) Economic information	
	ii) Energy consumption pattern	
	iii) Services	
	iv) Social aspects	
3.53	Inventory of existing biogas plants	39
3.6	Selection of priority areas	40
4. DEVELOPMENT OF TECHNOLOGICAL CAPABILITIES		43-57
4.1	Technological R&D	43
4.11	R&D policy formulation	43
4.12	R&D system development	43
4.13	Programme formulation	45
4.14	Operational procedures for the programme	45
	a) Identification of resources	45
	b) Technology transfer	46
	c) Technological option	47
4.15	Coordination of R&D efforts	48
4.16	Financing	49
4.2	Diffusion of the technology	51
4.21	Acceptability study	52
4.22	Demonstration programme	53
4.23	Construction and maintenance	54
4.3	Manpower development	54
4.31	Factors for consideration	54
4.32	Extension training	56
4.33	Construction training	56
4.34	Orientation programme	57
5. MICROLEVEL PLANNING		58-65
5.1	Factors for consideration	58
5.2	Resources and demand assessment at the microlevel	58
5.3	Policy options	59
5.31	Selection parameters	60
5.4	Operational scheme	61
5.5	Construction and maintenance	62
5.6	Summing up	64
6. FINANCING		66-69
6.1	Preamble	66
6.2	Financial plan formulation	66
6.3	Biogas Technology financing	67
	a) International	
	b) National	
	c) Local	
6.4	Recovery of assistance	68

Chapter	Page No.
7. INTERNATIONAL COOPERATION	70-73
7.1 Need for cooperation	70
7.2 Levels of cooperation	70
7.3 Areas of activity	70
a) Technical assistance	
b) Manpower development	
c) Financial assistance	
d) Information dissemination	
7.4 Agencies	71
ANNEXURES	
1. Variations of flexible gas holder model fixed dome model variations	1-1 to 1-5
2. Form for collecting data on existing biogas plants	2-1 to 2-4
3. Decision making points and the corresponding categories of information required for National Level Biogas Technology Development Plan	3-1 to 3-18
4. Fact sheet of training course of Biogas Technology extension workers	4-1 to 4-3
5. Construction training course for village masons	5-1 to 5-3
6. Orientation Programme Fact Sheet	6-1 to 6-2
7. Decision making points and their information requirements at the microlevel	7-1 to 7-8
8. Biogas plant for a 6 member family: Illustration	8-1 to 8-15
a) Decision for plant installation	
b) Plant installation and operation	
c) Realisation of financial assistance	
BIBLIOGRAPHICAL REFERENCES	1-2

Cha·ter I Introduction

1.1 Need for Renewable Energy Sources

Population growth and desire for better living standards of the people exert considerable pressure on the Third World agriculture and the traditional energy systems. This pressure is felt in the form of increasing demand for energy and energy consuming products and systems which require large scale resource mobilization and massive capital investments. It is being realised that such unprecedented investments and expansion of the conventional energy systems are neither possible nor desirable due to the finite nature of fossil fuels as well as the serious environmental and ecological consequences of their increasing exploitation. In this context, development and utilization of new and renewable energy sources such as sun, wind, biomass etc. are attractive in terms of their availability and suitability for decentralised applications.

Inspite of the continuing and ever increasing shift in favour of commercial energy sources such as coal, oil and electricity, almost 50% of the total energy requirements of Asian, African and Latin American countries are met by a single renewable energy source known as biomass. The annual biomass production in the world is estimated to be equivalent to four times the world's total energy consumption per year. However, present methods of biomass utilisation especially for domestic and agricultural purposes are energy inefficient and hence needs further improvements.

.2 Biogas: An Appropriate Energy Technology

Biogas technology (BT) offers an efficient way of biomass utilisation. It involves anaerobic fermentation of organic materials such as animal dung, agricultural wastes, aquatic weeds etc to produce a methane rich fuel gas and a value added organic fertilizer. Thus, it has considerable potential for providing fuel and fertilizer besides being a system for waste recycling, prevention of pollution and ecological imbalance and improvement of sanitary conditions in the rural areas.

Several developing countries in their quest for alternate and renewable energy sources, have realised the benefits of BT. In China, over 8 million biogas plants were installed during the last 12 years.

An estimated one lakh biogas plants have been installed in India mainly as part of an on-going national biogas project. Concentrated efforts are on in several other developing countries like Philippines, Thailand. Nepal, Sri Lanka etc. for further development and diffusion of BT.

No doubt these figures are promising but it should be noted that even in China and India, only a negligible part of the potential for biogas generation is being exploited. Inspite of the considerable efforts, the rate of diffusion of BT is very slow: majority of the biogas plants in China is built in the Sichuan Province alone and in India BT is still unknown to the majority of the rural people. Also, the performance and utility of existing biogas plants are far from satisfactory Recent studies of biogas plants in India, China and Thailand show that several of these plants are either being under utilised or have stopped functioning altogether.

The reported failure of the BT programmes could be traced back to lack of a well-founded plans and concentrated efforts on the part of the agencies responsible for the programme. It should be mentioned that the ultimate success of the biogas project in a country is decided by its acceptance in the rural households and its overall integration into the rural energy systems. It is found that religious, social, cultural and economic considerations often influence the diffusion of BT. This means that planning for biogas programmes should be preceded by a careful study of the various factors like energy options available, national priorities, socio-economic conditions of the people, meteorological and climatological conditions of the region etc. Such studies will help to ensure that BT either independently or in combination with other energy sources is a viable option for the country/region in question

1.3 The Manual: Objectives

The present manual is intended to provide a comprehensive set of guidelines to the decision makers to help them in planning, organising and managing regional/national/local biogas development programmes. The decision makers as a group include planners, policy makers, project/programme coordinators, financiers and even individual beneficiaries to some extent. The manual provides guidelines for ascertaining the technical feasibility, economic viability and social acceptance of BT in a given situation. In the event of a likely decision in favour of BT, the various factors to be considered in designing specific project activities are described. The manual is hoped to be of use to the different categories of decision makers associated with international aid agencies, national governments, financial institutions etc.

1.4 Conspectus

Chapter II gives a brief description of BT, its principles, processes, input materials that can be used, the major variations in plant models etc. The merits of biogas energy and the problems involved in the plant installation and sustained operation are given with special reference to the policy measures to be taken to improve the situation. Moreover, a methodology for quantitative and qualitative evaluation of this technology vis-a-vis other currently used energy and fertiliser technologies is also given.

Chapter III deals with the formulation of a National BT Develop-- ment Plan. A broad introduction to the magnitude and diversity of factors to be considered is given in the pre-planning considerations. Further on, the details of the planning processes are given including the organisa-tional set-up necessary for carrying out the plans, various studies and evaluations to be carried out like demand and resource assessment, purpose and methods of identifying the energy technologies appropriate to the nation and how to assign priority to these energy technologies. These exercises will give a clear understanding of the position of BT in the national energy scene and the programmes to be carried out accordingly.

Chapter IV gives the planning of these specific programmes: the technological R&D, diffusion of the technology and manpower development etc. Technological R&D includes the R&D system development programme including technology transfer, specific areas of research, R&D project monitoring, financing, etc.

Diffusion of technology has to be planned in the wake of its acceptability at the national, regional and local levels. A well defined demonstration programme is a key factor in diffusion. Equally important are the infrastructural, financial, material facilities to be supplied to back up the diffusion programme.

Manpower development should consider the different categories of manpower required - extension agencies, construction workers, development functionaries etc. and above all the steps to be taken for developing the required manpower.

Chapter V is with reference to the local and individual (beneficiary) levels. The different stages involved in local level planning, options available, specific decision making points in the actual installation. operation and maintenance of plants etc. are provided in this chapter.

Chapter VI gives the financial provisions to be made for the different stages of BT development. Cost reduction mechanism, amount and sources of finance, the nature and extent of assistance to be provided to the beneficiaries etc. are also given.

Chapter VII gives the probable areas of bilateral, regional or global cooperation for BT improvement and adoption, and the agencies currently active in this. The various modes of cooperation like technical or financial assistance, manpower development, dissemination of information etc. are given.

Chapter II Biogas Technology

2.1 Definition

Biogas Technology (BT) refers to the anaerobic fermentation of organic materials by a group of micro-organisms called methanogenic bacteriae in a specially designed tank to produce a gaseous mixture of methane and carbon dioxide called biogas and a residual sludge.

Biogas is a convenient fuel for cooking, lighting and even for powering prime movers. The residual sludge is rich in nitrogen in the form of ammonia and hence an excellent organic fertilizer.

2.2 Main components

Biogas production usually involves installing a biogas plant, charging the plant with a slurry of organic materials and water, allowing the charge to get digested and storing the biogas produced under pressure before it is piped to the points of use. A schematic representation of biogas production is given in Fig. 1.

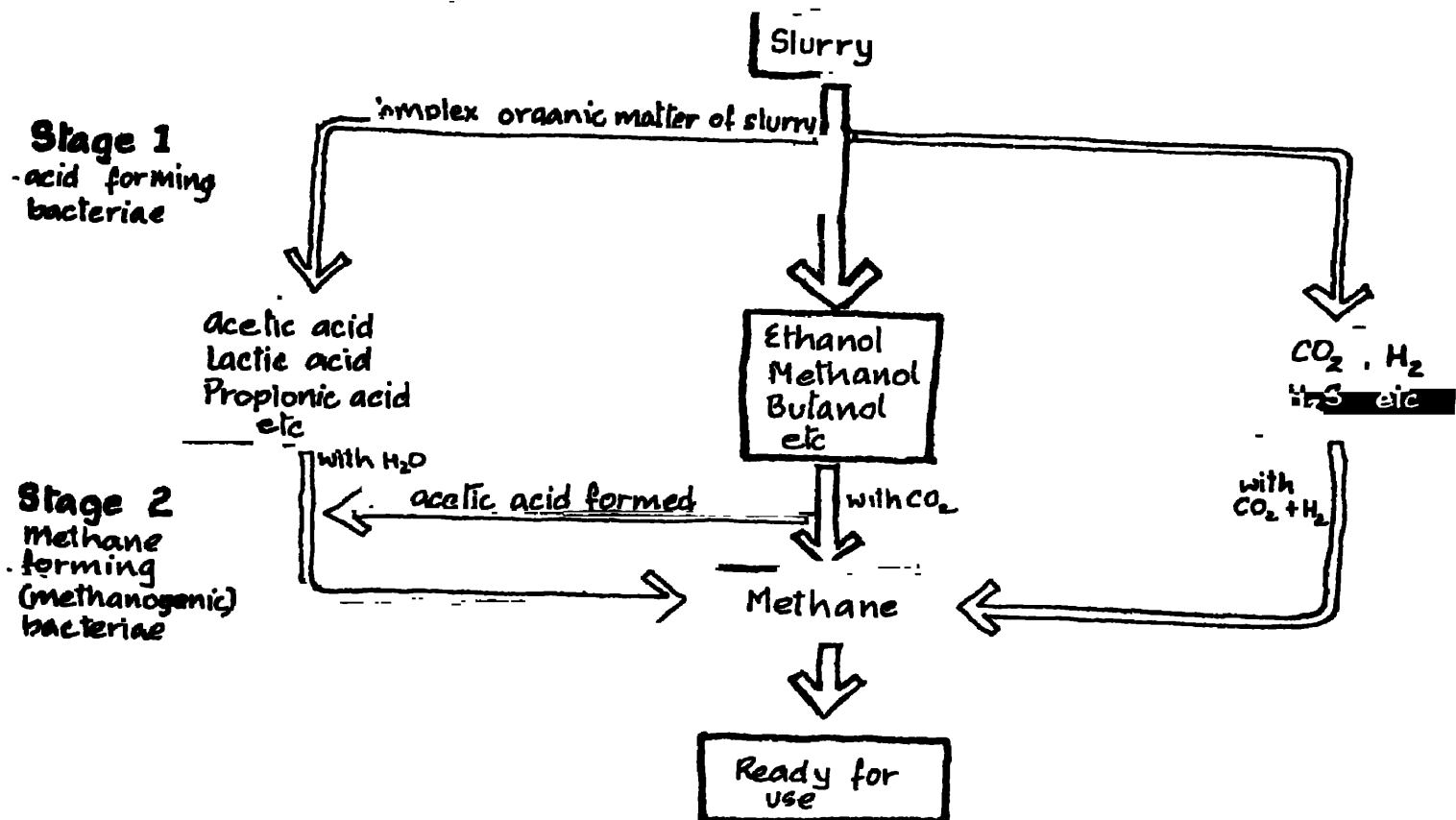



Figure 1 Biogas Production : Schematic Representation

Important terms used in discussing BT are given below

Important terms

Term	Description
Biogas plant	An installation for the anaerobic fermentation of organic matter which consists of an airtight tank with suitable input and output provisions and a gas holder for collecting and storing.
Digester	An airtight tank where the fermentation takes place. It receives the slurry through the outlet pipe.
Gas holder	The digester may or may not be attached to the digester. If the gas holder and the digester are integrated into one unit, the gas holder could be a floating drum or a fixed dome. The gas holder in some cases is a separate unit connected to the digester by a pipe.
Family plant	To cater to the cooking and lighting needs of an average family. The smallest size of a family plant is 3 m^3 in terms of the volume of gas produced per day.
Community plants	To meet the partial/complete energy and fertiliser needs of a village/community. It could even be attached to public places like schools, offices etc. There is no fixed size for community plants. The size is decided by the need.

Term	Description
Organic materials	Any material in which carbon is fixed organically, e.g. animal and human excreta, agricultural wastes, aquatic plants, etc. Any organic material is a potential INPUT MATERIAL for biogas production.
Slurry	A mixture of the input materials and water in the ratio 4:5 or 1:1 thoroughly mixed and fed to the digester. The solid content of the slurry is around 10%.
Anaerobic fermentation	A complex microbiological reaction by which under anaerobic conditions the input materials are broken down to produce methane, carbon dioxide.
Micro-organisms	Microscopic living beings responsible for several natural changes including anaerobic fermentation. Several strains of bacteriae are usually involved. The exact nature of reactions and taxonomy of these bacteriae are yet to be understood.
Fermentation conditions	The optimum conditions are : temperature 30-40°C; solid content - 10%; pH - 7 to 8; carbon -nitrogen ratio 30:1 etc.
Retention time	The period of time the slurry should be held in the digester to complete optimum anaerobic fermentation. Under optimum condition, 80-90% of total gas is produced within 50 days.

Term	Description
Toxins	The micro organisms are easily affected by materials like sulphates, sodium chloride, cyanide, nickel etc. These toxic materials should be either absent in the slurry or their concentration should be diluted by adding water.
Scum	A layer of floating solids formed on top of the standing slurry. Methane formation will be inhibited if the scum is allowed to accumulate and set hard.
Batch digestion	The input materials are fed to the digester at the start of the process and sealed and allowed to ferment. At the completion of fermentation, the sludge is emptied to pits and the digester is reloaded with fresh input materials. In this process the gas production varies. It is considerably slow at the start, passes through a maximum and then declines towards the end of the digestion process.
Continuous digestion	This process is characterised by regular feeding of the slurry; an equivalent volume of sludge flows out through the outlet pipe. Within few days of charging the digester, the gas production stabilises.
Gas production	This the quantity of gas produced per unit of time and it is normally expressed as ft^3/day or m^3/day. This should be always quoted under standard conditions of temperature and pressure.

Term	Description
Biogas	It is the gaseous mixture produced during anaerobic fermentation of organic materials. It consists of methane (60-70%), carbon dioxide (30-40%) and traces of hydrogen sulphide, nitrogen, hydrogen, oxygen, carbon monoxide etc. Presence of methane makes it combustible.
Sludge	The residue after digestion which consists of undigested solids and nitrogen (as ammonia), phosphorous, potassium and several trace elements. It is a good soil conditioner and an organic fertilizer.

2.3 Biogas Plant Models

A number of biogas plant designs are available. For a schematic presentation of the functional components see Fig. 2 below.

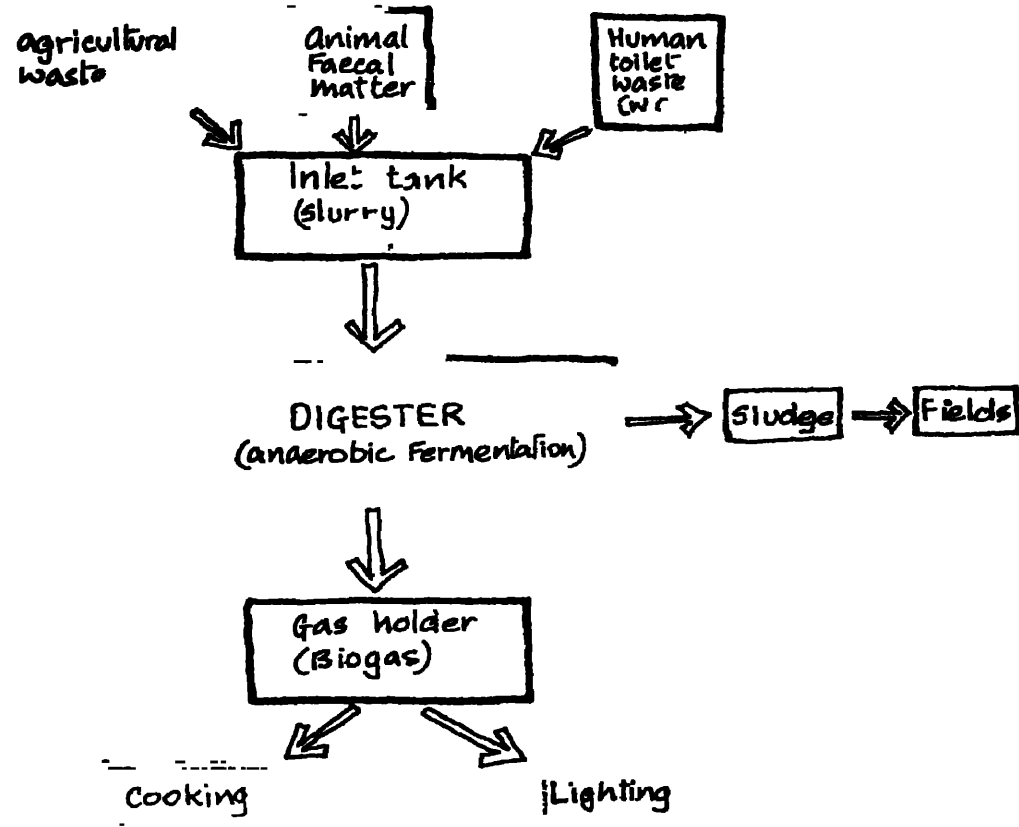



Fig2 Biogas Plant: Schematic Representation

Biogas plants could be broadly classified into two types : (1) Plants with movable/flexible gas holder, (2) Plants with built-in (fixed) gas holder.

Biogas plant with movable gas holder

Indian biogas plant is a typical example of this type of plant. The metallic gas holder floats on the digester slurry.

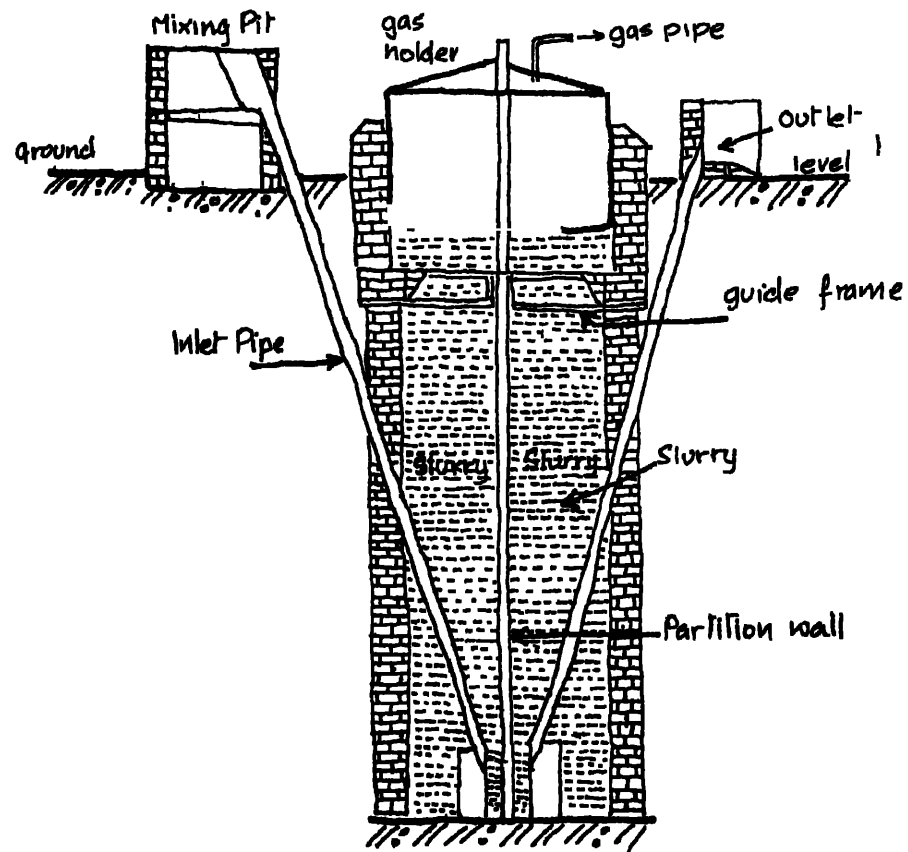



Fig 3 KVIC model (India)

Advantages	Disadvantages
Gas pressure is regulated by the weight of the gas holder	Metallic gas holder is exposed to the atmosphere and causes heat losses. As it dips in the slurry anti corrosion treatment required.
Scum breaker could be attached to the gas holder.	Gas holder is expensive.

Fixed Dome Bio-gas Plant

In this type of design, a masonary dome type structure forming the upper part of the digester acts as gas holder. See Fig. 4.

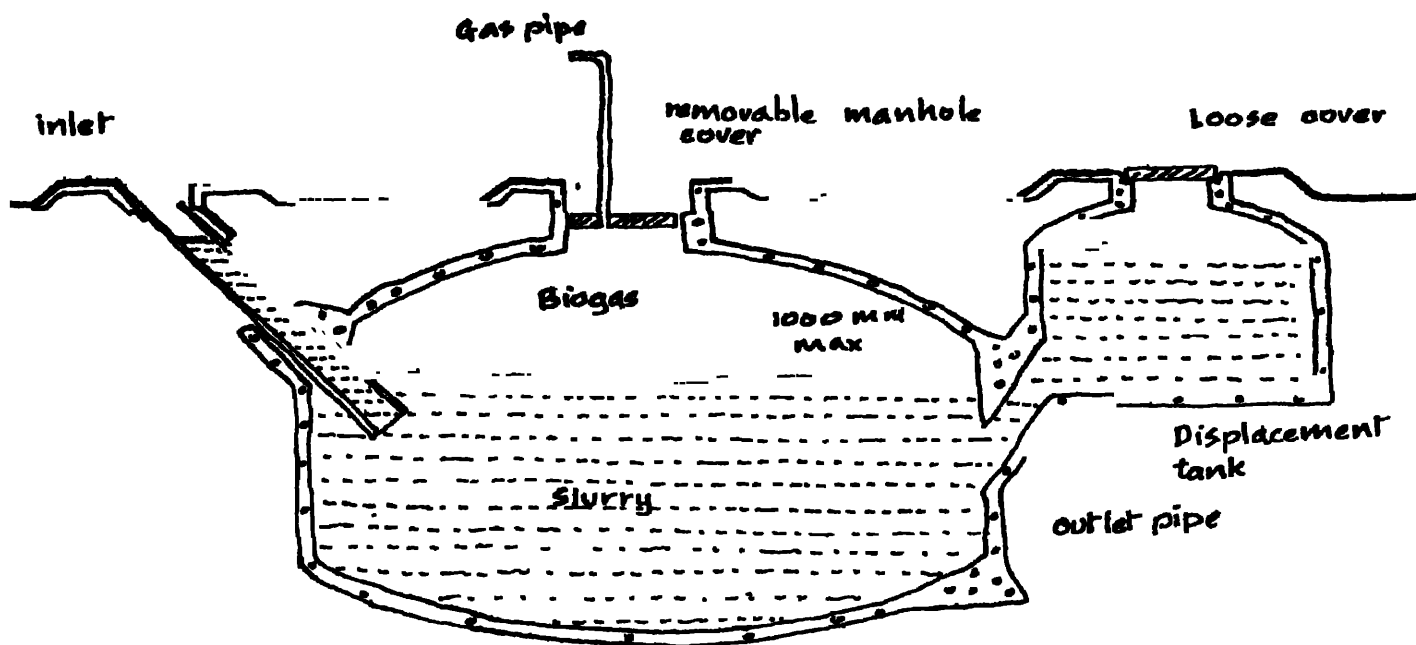



Figure 4 Chinese Model (Szichnan Province)

Advantages	Disadvantages
Since it is underground, the plant space can be utilised.	Construction needs special skill.
Fairly steady temperature can be maintained inside the digester.	Stirring and scum breaking is generally difficult.
Construction cost is low.	Gas pressure control is difficult.

Both the movable gas holder type biogas plant and fixed dome type biogas plants have several local variations. These variations alongwith their advantages and disadvantages are given in Annexure 1.

2.31 Selection of a Model

Selection of a model depends on the geographical, economic and other conditions prevailing in the country. Given below are some of the parameters for selection:

a) Technical

It is better to select a model which does not necessitate high construction skill. The flexible gas holder type plants can generally be constructed with moderate skill. Construction of the fixed domes on the other hand involves great skill and care.

Another factor is the provision for breaking the scum formed on the slurry. The scum might prove a vertical factor in the long run. Generally attaching a stirrer in the flexible gas holder type plants is easy, while in the fixed dome type a rod will have to be inverted through the outlet pipe and the slurry stirred. This may not be effective.

Equally important is the mechanism for removing the sludge, especially if it is a continuous fed model. In majority of the flexible gas holder models, the sludge collection is by automatic gravity flow whereas in the fixed dome Chinese (Szechuan) model the sludge has to be pumped or removed periodically by buckets.

b) Economic

The plant selected should be cheap. One way of ensuring this is to use locally available materials for construction as in the Chinese (Szechuan) model. Cost of maintenance also should be as low as possible. Steel gas holders generally require frequent painting thereby increasing the maintenance cost.

In developing countries, the plant parts will have to be taken to rural areas with very poor transportation facilities. Carrying the steel gas holder to these areas or fabricating it locally may be difficult. Under these conditions, portable bag type plants may be viable option. The Chinese design also offers possibilities of application since it can be constructed with locally available materials.

c) Geographical

Generally all models are suited to places where the digester pit can be excavated to more than 3 m without blasting.

However, the Indian horizontal plant and the Nepalese tapering model are designed to locations marked with the presence of hard rock and high water table.

d) Climatic

The rate of biogas production tends to decrease during winter. In the underground fixed dome plants the temperature will be comparatively steady and optimum due to the natural coating of earth on their top.

In actual practice, one may have to select a model offering the maximum possibilities and modify it suitably.

2.4 Advantages and Limitations

The impact of BT on the national demand for fuel and fertilizer are important considerations for decision making. Advantages of the technology can be viewed from two different levels :

Advantages of Biogas Technology

National level	Individual level
Saving foreign currency on conventional commercial sources of fuel and fertilizers.	Source of convenient, clean and fast fuel for domestic needs.
Diversion of commercial fuels for industrial purposes.	Source of better quality fertilizer and soil conditioner.
Reducing the need for expensive distribution of energy in rural areas.	Source of better, cheap food.
Increased agricultural production.	Increased agricultural production.

National level	Individual level
Increasing rural employment potential.	
Prevention of deforestation and its ensuing benefits.	
Improved rural sanitation and health.	
Reduced air and water pollution etc.	

However, there are certain factors limiting the acceptance of this technology among the people. These can be broadly categorised as technical, economic and social problems and are experienced more at the individual or the actual beneficiary level (5, 13). These problems can be solved or their intensity can be reduced by a concerted effort on the part of the local, regional and national authorities concerned with the biogas technology. Some policy implications of these problems and their solutions are given below :

Technical Problems in Plant Operation

Type of problem	Causes	Policy implications
Gas plant associated	Hydraulic pressure of ground water on the plant, soil characteristics, corrosion of gas holder, scum formation in the slurry, clogging, break-down of pipes, deterioration of gas mains etc.	Programme for better training of extension workers and masons (Manpower Planning) for proper installation: education of beneficiarie for proper maintenance including replacement of plant parts (Extension Planning), new approach towards developing appropriate construction materials (R&D Planning) etc. needed.
Operation associated	Lack of sufficient quantity of bacteriae. Fluctuations in slurry consistency Lack/excess of conditions like pH, temperature etc. for fermentation.	Programme for proper training and education of beneficiaries in the operation of the plant. (Extension Planning)

Type of problem	Causes	Policy implications
Production associated	Seasonality of gas production.	Methods for developing techniques for maintaining slurry temperature (R&D Planning)
Storage associated	Storage in liquid form not possible. Gaseous form storage needs containers which need special manufacturing skills. Storage and transportation beyond 20 m not economical.	Proper planning of energy needs and input availability before installation. Machinery for storage should be justified by the availability of gas.
Utilisation associated	Special devices are necessary for using biogas.	Mechanism for evolving cheaper, more efficient utilisation devices necessary. Similarly, methods of analysing and conditioning the slurry be deviced (R&D Planning).

Note : Many of these problems can be solved by studying the local situations carefully and planning accordingly. If neglected, these would affect the promotion of BT considerably.

Economic problems relate to the following characteristics of BT.

Economic problems

Nature of problem	Policy implications
High initial capital investment and low economic return.	New approaches towards developing cheaper techniques of construction (R&D Planning); evolving programmes to finance a portion of the capital investment (Financial Planning).

Nature of problem	Policy implications
High opportunity cost.	Programme methods for popularising the indirect benefits also of the technology. Emphasise integrated biogas systems (R&D and Extension Planning).
Scarcity of input materials.	Proper assessment of demand and resources to be done; promotion of community plants wherever possible. (Extension Planning)
Limitation imposed by the traditional energy system. (Depriving the poor people of their fuel source, i.e. cattle dung).	Proper planning before plant installation; methods to encourage community plants if applicable.

Social problems

Often the beliefs, prejudices, habits etc. prevailing in the society pose problems for promotion of the technology. Educational background, income of the beneficiaries etc. may also affect the speed of BT adoption.

This has to be tackled in 2 ways - (1) Try to introduce the plant models most suited for the area (Local level Planning), and (2) Device suitable training of extension workers to enable them to take the message of BT to the people. (Extension Planning)

2.5 Existing Energy/Fertiliser Sources and BT: A comparison

The word 'alternative technology' is used here to indicate the alternatives available for BT. For practical purposes only, the fuel and fertiliser sources currently in use are considered. While considering any other renewable energy source, a similar exercise comparing the source with its existing alternatives will have to be carried out.

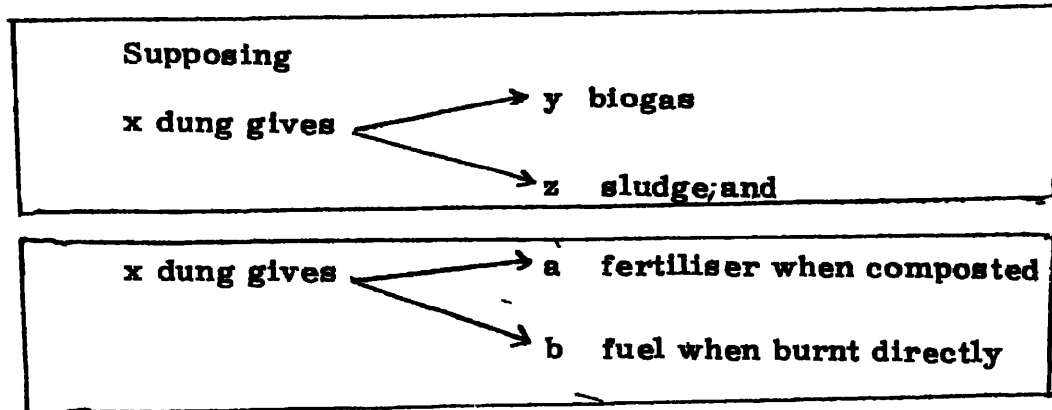
The benefits of BT are difficult to be quantified and depends to a great extent on the current practice of energy use. BT has the dual advantage of meeting both the fuel and fertiliser requirements of the nation. No single alternative having this combined benefit exists. Hence some of the conventional sources of fuel and fertiliser are taken out and compared with BT.

A comparison of existing alternate fuel/fertiliser source and BT.

Type of sources	Merits	Demerits
a) Sources of fuel		
1) Using the material directly as fuel (firewood, dried dung)	No capital investment needed. (Individual level)	Partial satisfaction of fuel requirements. (National level). Fertiliser has to be purchased (both at the individual and national levels).
2) Having fuelwood plantations	Not much capital investment at the individual level	Adequate land to be ensured; meets only partial fuel needs; fertiliser to be supplied; affects the ecosystem (National level). Might be expensive for a poor farmer.
3) Electricity	Complete fuel needs met; it is clean, more efficient than the above sources (individual level)	High capital investment, transmission loss (at the national level); not cheap (at the individual level).
4) Petroleum fuels and charcoal	Clean and efficient (invidivual level)	It is a fast depleting source; high capital investment; highly expensive (national level). Expensive and perhaps even scarce (at the individual level)

Type of sources	Merits	Demerits
b) Sources of fertiliser		
1) Compost	No capital investment. (Individual level)	Time-consuming procedure. Quality not so high as the sludge. All fuel needs are to be met separate (individual level)
2) Chemicals	Ready source of fertiliser. (Individual level)	High capital investment; quality is not so high; leads to ecological imbalance in the fields in the long run (national level)
c) BT	Clean, efficient fuel; source of good quality fertiliser and soil conditioner (individual level)	High capital investment; may not meet complete fuel and fertiliser needs; daily operation is a problem; (individual level); rate of adoption will be rather slow; meets only partial fuel and fertiliser needs (national level)

The variables that can be used for an economic evaluation of these alternatives are :

a) The volume of fertiliser slurry and gas produced by a volume of the organic waste compared to the fertiliser and fuel value of the wastes when used directly for scientific composting or as fuel; in other words

The values of a and b when compared with y and z show the best option possible with x volume of dung.

b) The value of biogas in terms of the equivalent energy from kerosene, electricity and such other sources i. e.

"y" value of biogas substitutes y_1 value of electricity/kerosens etc.

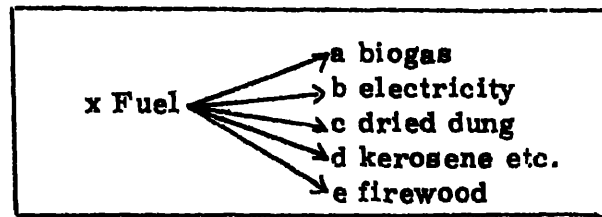
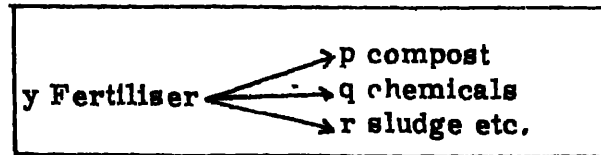
c) The value of sludge in terms of its equivalent value of fertiliser; or

"z" value of sludge substitutes z_1 value of compost/chemical fertiliser etc.

d) The indirect costs and benefits of all these sources of fuel/fertiliser. (14, 23)

Thus given a steady supply of organic waste materials, the options are to (15)

a) install a biogas plant and use these materials; or
b) use the wastes for composting; or
c) use all/some of them directly as fuel.

In practice, the cost of obtaining the same amount of fuel and fertiliser for the above three options as well as from other conventional sources mentioned above would vary from country to country and perhaps even among the different regions of the same country, i. e. to get

and for

Generally the cost analysis of the sources currently in use will be available in the respective departments or with concerned authorities. Hence the deciding factors for cost analysis of BT only is given below :

- initial investment in biogas plants;
- interest, depreciation and maintenance costs;
- volume of biogas generated;
- effective heat obtained from biogas;
- quantity of fertiliser produced;
- supplementary purchase of other fuels like kerosene, dry dung cakes, chemical fertilisers etc. if necessary.

A country can choose any one or a combination of these alternatives for meeting its fuel and fertiliser requirements. National considerations pay an important role in the selection of the energy mix suited for a country.

Chapter III Biogas Technology Development Plan

3.1 Introduction

This chapter deals with ascertaining the role of Biogas Technology (BT) in the overall energy/fertiliser scene of the country, framing the policy imperatives for BT development and promotion and formulation of a Long Term Development Plan for implementing the policy decisions.

3.2 Role of BT

Ascertaining the potential role of BT in a country requires tentative assessment of the energy/fertiliser requirements of the country, the potential of the technology in meeting these requirements and the capability of the country to support the required development programmes. The factors to be considered in this analysis are given below :

Possible Applications of BT

Problem to be solved	Elements of analysis
1. To provide energy	- National energy requirements, overall figure as well as sectorwise break-up. - energy consumption pattern (current and future) - present and future supply of different types of energy sources - quantity of biogas likely to be produced etc. - types of use of biogas: cooking/lighting/running engines.

Problem to be solved	Elements of analysis
2. To provide fertiliser	- Fertiliser requirements of the nation (present and future) - fertiliser consumption pattern (present and future) - supply of fertilisers (present and future) - quantity of sludge that can be used as fertiliser etc. - crops that could use sludge.
3. For environmental development	- Types and quantity of organic wastes and their disposal which cause environmental contamination - environmental benefits of using biogas as a replacement of conventional cooking fuels - avoiding environmental pollution caused by fertilizer industry.

BT Potential

Potential	Elements for analysis
1. Availability of resources	- Input materials available (types, quantity) - input materials that can be used for BT - possibility of using these materials completely - construction materials available (types, quantity, market price)

Potential	Elements for analysis
	- types and quantity of materials available for plant construction - other facilities like agricultural land, pasture land, utilisation devices like cooking stoves, lamps, etc.
2. Existing biogas plants	- Location, model, capacity etc. of plants - operational status of plants (being used/ partially being used/ not used at all) - number of family/individuals served by these plants - types of use made of the products etc.
3. Other facilities	- Transportation facilities available - geographical peculiarities - climatological considerations - ecological/environmental considerations etc.
4. Possibilities of use of products	- Quantity of biogas likely to be produced - quantity of sludge likely to be produced - probable types of use of biogas: cooking/lighting/ use in engines etc. - types of use of sludge (crops responsive to sludge/quantity of sludge needed/mode of use of sludge/using sludge in aquaculture)

Potential	Elements for analysis
	- proportion of total energy/fertiliser need that can be met by biogas/sludge.
5. Economic potential	- Cost of plant construction, manufacture of equipments etc. - other items of expenditure like training, extension etc. - value of energy produced from biogas - value of fuels substituted by biogas - value of fertiliser substituted by sludge - value of producing equivalent quantity of energy/fertilizer from other sources etc.
6. Priority that can be attached to BT	- Types of current and proposed energy projects - types of current and proposed fertiliser projects - areas where proposed projects w ll be implemented - performance evaluation of existing energy/fertiliser projects - proportion of energy/fertiliser met by the existing plants - proportion of energy/fertiliser likely to be met by the proposed plants - number, size and cost of proposed energy projects

Potential	Elements for analysis
Priority that can be attached to BT	- number, size and cost of proposed fertiliser projects - population to be served by each of these projects - prospects of making integrated use of byproducts - prospects of using local resources (man, material) - continued availability of resources for each project - employment potential of each project - indirect merits/defects of each project - cost-benefit study of different energy/fertiliser mix

National Ca·:bilities

Capability	Elements for analysis
1. Planning	- Organisations/institutions/experts; experience with other similar projects
2. Resources and demand assessment	- Organisation/institutions; existing studies/evaluation of resources and demand
3. Development of technological capabilities	- Inventory of existing Biogas plants - institutions engaged in R&D - human resources potential - plant models developed/adopted etc.

Capability	Elements for analysis
4. Technology diffusion	- Institutions/organisation concerned with technology diffusion (voluntary organisations/local co-operatives/regular employees of Agric. Extension Units etc.) training institutions available facilities for construction/operation (plant parts/utilisation devices/repair facilities etc.)
5. Human resources	- Types and number of human resources available (construction workers/extension workers/field officers of banks/R&D personnel etc.) - facilities for developing the necessary expertise
6. Financing	- Amount available/required - sources of finance (local/regional/national/international) - forms of assistance, means of recovering the amount etc.

3.3 Policy formulation

If the decision helped by the above analysis is in favour of BT, specific policy imperatives are to be made regarding its development and promotion. In this context the following points may be considered :

- To start with, the decision to implement BT Development Programme can be based on the already available information.

- Later, necessary modifications can be incorporated in the light of the detailed studies undertaken as part of the programme.
- Development of BT necessitates co-ordination with other sections of the economy like Rural Development Sector, Energy Sector, Agricultural Sector etc.

Policy formulation should identify and define :

- felt needs of fuel and fertilizer
- priority assigned to BT
- targets attainable over the plan period
- incentives for capital investment
- anticipated benefits and impacts of the programme. (20)

Fig. 5 shows the stages involved in policy formulation.

3.4 Plannin. and programming

3.41 Organisational Set up

Once a policy decision for the development and promotion of BT in the country has been taken, the organisational set up necessary for its implementation is to be identified. This involves the following (6, 12)

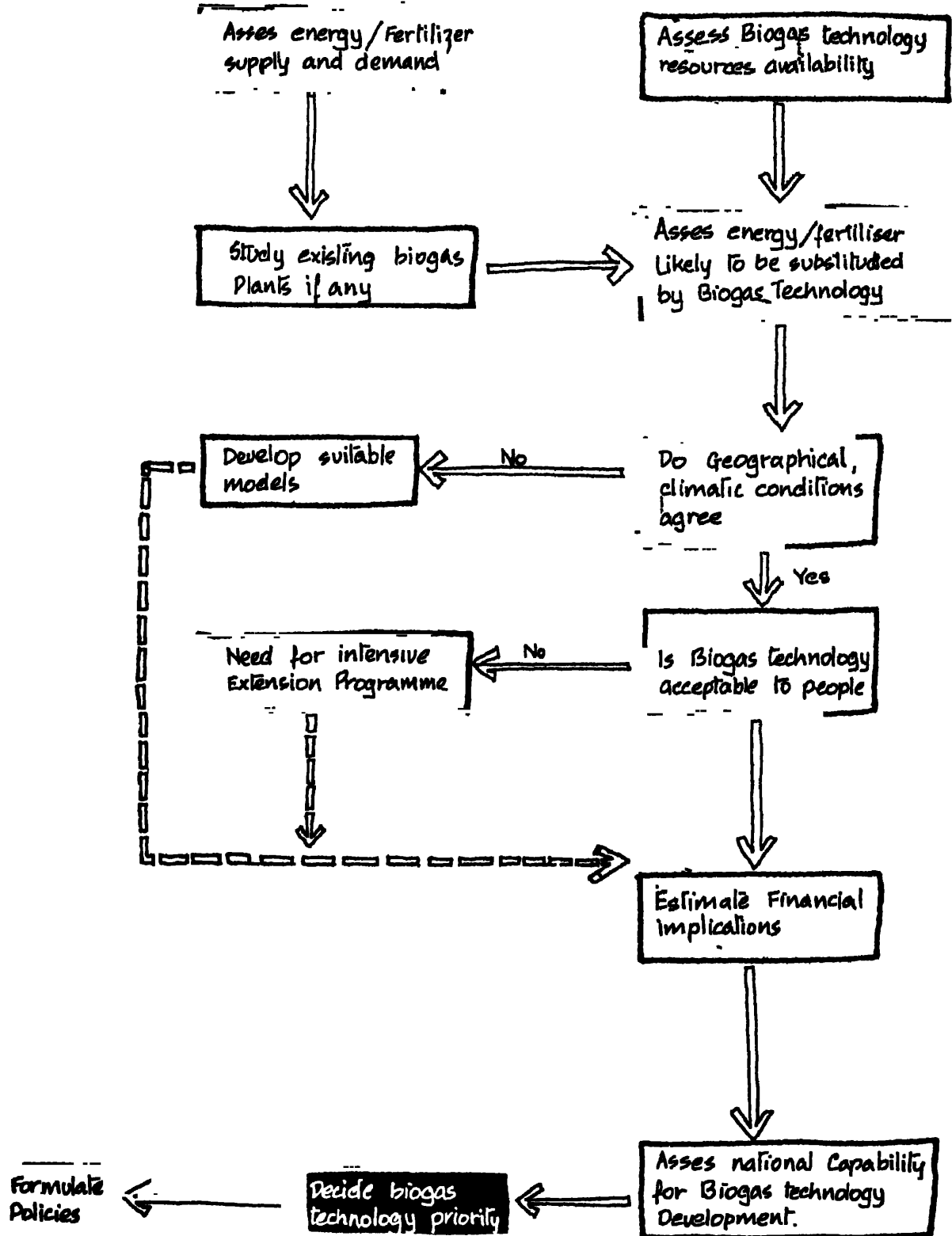



Fig 5. Biogas Technology Development Policy formulation

- To identify the governmental sector responsible for the implementation of the programme. It could form part of the national energy sector or rural development sector etc.
- To set up a national coordinating body to ensure cooperation of all other departments and to plan and review the programme. This could be the ministry of small scale industry, ministry of agriculture, the ministry of rural development or the ministry of general planning which is in coordination with all other ministries. (It is always better to integrate BT development activities into an already existing national authority rather than setting up an independent authority for BT development).
- To identify an agency for BT development planning and programming. This special body could be the department of planning of the competent ministry or the planning department of the national institution/organisation responsible for energy or rural development programmes.
- To identify or set up national agencies responsible for technological capability development, diffusion, manpower development, financing etc.
- To identify, or set up competent regional governments/institutions and other statutory bodies, in the case of decentralized political system
- To identify and strengthen grass-root level organisations for undertaking specific tasks of the programme
- To identify and involve expertise from interdisciplinary and specialised areas in the programme.

a) National Agency for BT development

Functions of the National Agency for BT Development are the following :

- Propose development policies and strategies
- Formulate plans: both short-term and long-term plans
- Formulate time-bound action programmes
- Coordinate and motivate units responsible for R&D training, financing etc.
- Coordinate regional, local agencies and other statutory bodies involved in the programme
- Coordinate and cooperate with
  - units under the same and different sectors of the economy
  - international agencies to be involved in BT development etc.

b) Regional Agency

Regional Agency in its turn has the following functions :

- Overall planning and execution of the programme.
- Coordination of the activities of the various agencies.
- Facilitation of institutional financing.
- Arrangement for input materials.
- Project monitoring and programme evaluation.
- Serving as a nodal point for the national coordinating unit.

c) Microlevel Agencies

BT development programme could be assigned to several micro-level agencies :

- Administrative units and functionaries such as village panchayats, extension officers etc.
- Co-operative enterprises etc.,
- Voluntary agencies, and
- Community establishments, schools etc.

Terms of reference of these microlevel agencies will be

- take steps for popularising the technology;
- mobilise support from the community for the adoption of the technology;
- seek measures for maximum community participation;
- provide technical, financial and managerial assistance for the operation and maintenance of plants;
- coordinate the work of community plants;
- provide advise/guidance to the private enterprises;
- establish liaison with the regional and national level authorities.

The choice of the appropriate administrative mechanism at different levels depends on the socio-economic, political and other characteristics of the country. However, due to the inherent nature of BT, a concerted effort on the part of the national government is necessary for the popularisation and optimum use of the technology, especially in developing countries. (6)

3.42 Plan Formulation

The Unit for Planning and Programming should formulate both short-term and long-term plans. The immediate step is to formulate a short-term plan with a view to carry out certain specific projects. The overall Development Plan which requires information on several aspects like energy needs, resource availability, establishment of priorities etc. may also be drawn up simultaneously.

3.421 Short-Term Planning

The short-term plan helps framing a one- or two-year implementation programme which should take into consideration, the following :

- Identification of immediate needs and existing facilities;
- identification of incomplete or abandoned biogas plants (for analysing the reasons for failure);

- installation of pilot/demonstration plants (for technological evaluation and popularisation).

The short-term plan and its respective programmes would facilitate initiation of the project without having to wait for the integrated overall development plan; rather, it provides sufficient time and experience for framing the Development Plan. Moreover, it helps to demonstrate the technology thereby establishing its viability or otherwise, and stimulating its adoption and also the development of communal self-help projects.

3.422 Development Plan

Overall development plan, on the other hand, calls for a series of preliminary studies and evaluations on the technological, socio-economic, financial, managerial and other aspects of BT development. The existing potential, present and future demand for the technology, the number, operational status etc. of the existing plants, investment and cost indices etc. form part of such studies. Further, specific plans like institutional plan, technology plan, financial plan etc. need to be formulated as they would form the basic framework for a development strategy. (8)

Factors for consideration in the Development Plan

- potential of BT;
- resources availability (input and construction materials, utilisation devices, human resources etc.)
- geographical, climatological and other distinctions prevailing in the country;
- assumed rate of acceptance of the technology in the country (realistic estimation of social acceptance, probable areas and magnitude of diffusion over a period of time etc.)
- technological capability of the country and methods for its development (material facilities for R&D, expertise, feasibility of the available know-how etc.)

- capability/methods for diffusion (human, material and financial facilities for extension, socio-cultural and religious problems etc.)
- human resources potential (categories of development functionaries, institutional facility for their training and deployment etc.
- financial resources (amount required, amount available, appropriation of the amount sanctioned, sources of finance, etc.)

3.43 Phased out Programme for Development

BT Development Programme will have to be phased out over a period of few years. The following factors are to be decided during each phase :

- upper and lower limits of number of plants to be set up;
- rate of acceptance of the technology by the people;
- areas to which the programme has to be spread;
- type of plant to be propagated;
- economic strata of the people among which the technology has to be introduced;
- facilities to be provided (R&D laboratories/ training institutes/small-scale factories etc. to be set up);
- financial resources available;

3.5 Resources and Demand Assessment

Overall assessment of resources and demand is the main frame of reference for formulating the Development Plan and its programmes. This is intended to evaluate the current energy situation and to assess the prospects of application of BT in the country. (9)

The different steps involved in the overall evaluation of resources and demand are :

- evaluation of resources
- evaluation of energy needs and demand and
- inventory of existing biogas plants, if any.

3.51 Evaluation of resources

Overall evaluation of resources aims at assessing the resources potential of the country and to identify areas offering the best possibilities of application of BT. (19) As ecology, geography, meteorology etc. also have a relationship with its resources, studies in these areas need to be undertaken.

i) Input materials

This seeks to assess the types of input materials available in the area and thereby the quantity of biogas that can be produced. Elements to be considered in the evaluation of input materials are :

- type of materials
- quantity of materials
- gas production per unit of input
- methane content of the gas produced
- quantity and quality of sludge produced.

Assessment of these materials may not be readily available but could be calculated.

In the case of ANIMAL MANURE the best method is to estimate the quantity of dung available per day per animal and to translate it in terms of the cattle population of the area. For this

- distribution of households according to ownership of livestock
- statistics relating to the number of cattle death during a specific period
- type, quantity of feed/fodder provided
- stabling habits etc.

are to be considered (cattle population here includes even pigs, chicken, goats, etc.). A country can arrive at a definite unit of the input material available in relation to its population. e.g. 1 cattle unit per capita of population, 1 cattle unit being 1 cow or 5 pigs or 250 laying hens or 20 kg of equivalent other organic wastes as the minimum quantity of feed material available daily. (7) However, dung availability is determined to a great extent by the size and diet of the animal, grazing habits etc.

As regards NIGHT SOIL, much depends on whether the households are connected to toilets or not.

A realistic estimation of PLANT WASTES especially fresh weeds, grass, stalks, etc. may not be possible. However information on the type of crops available, cropping pattern, area of land under cultivation etc. can be obtained which might help in the estimation of rice and wheat STRAWS AND OTHER CROP RESIDUES available.

Data on the distribution of households according to the use of different water sources for various purposes are to be collected, since water is an important input in the preparation of the slurry.

ii) Commercial energy sources

- probable sources of fossil fuels like coal, petroleum etc.
- proven sources of fossil fuels like coal, petroleum etc.
- availability of hydro electricity, geothermal energy etc.

iii) Construction materials

The purpose of this study is to locate and evaluate the different types of materials used for construction of biogas plants. The elements to be considered are :

- local deposit of stones, gravel, coarse sand, limestone etc.;
- availability of other building materials like bamboo, bricks, mild steel, galvanised iron, etc.
- the price of these materials;
- demand of these materials in other fields (housing, etc.).

iv) Accessary facilities

This is to assess the availability of accessary facilities like land, utilisation devices, etc.

Factors to be considered :

LAND

- area covered by forests;
- area of pasture land available;
- area under cultivation;
- land use pattern;
- distribution of households according to farm size;
- distribution of land holdings;
- distribution of households according to size of open yard etc.

UTILIZATION DEVICES

- types of cooking stoves used;
- types of illuminating devices used;
- distribution of households according to the use of cooking stoves;
- distribution of households according to illuminating devices;
- price of stoves and illuminating devices;
- agencies for manufacture, sale etc. of these stoves and devices;
- number, facilities etc. of workshop for repair.

v) Ecology

Biogas programme is inter-related to distribution of agricultural land, types of forest reserves, forest plantations, investments in forest production and such other programmes. Hence, decision on BT development in an area where natural harmony is already disturbed by population pressure and human activity should consider two equally important but inversely related ecological factors :

- the possibility of recovering exhausted region in the wake of additional cattle for biogas production (BT may imply a growth in cattle population) and
- the potential of replacing forest resources by biogas for meeting energy needs and thus ensuring less deforestation (by cooking on biogas instead of firewood).

vi) Geography

The purpose of graphical evaluation is to determine the nature, characteristics, and composition of the soil and sub-soil with a view to help in the selection of the construction criteria and the plant model.

Factors for consideration

- soil conditions, soil fertility, erosion etc.;
- sub-soil conditions: presence of hard rock;
- water table;
- soil stability, etc.

vii) Climatology

Information on geographical location of the area, climatic changes, weather conditions, temperature variations in a season and in different seasons, average annual rainfall etc. are to be collected.

3.52 Evaluation of energy needs and demands

This together with information on the overall resources of an area go into establishing the relevance of development of BT in the area. The important aspects to be considered for analysis of energy needs and demand are the following :

i) Economic information

With reference to a given area, it includes

- the number of households;
- distribution of households according to size;
- distribution of population according to occupation, age group;
- educational status of the people;
- educational facilities available;
- income distribution;
- settlement patterns;
- migration patterns;
- distribution of rural industries: types, employment, potential;
- import/export information;
- balance of payment situation of the nation;
- financing of development expenditure: sectoral break down; types of sources, etc.

ii) Energy consumption pattern

For estimation of the current and future requirements of energy,

- distribution of traditional fuels;
- commercial energy potentials;
- consumption pattern of traditional fuels;
- consumption pattern of commercial fuels;
- per capita energy consumption - aggregate as well as individual sources;
- total fuel energy use;
- seasonal variations in fuel use;
- price of different sources of energy;
- consumption of chemical fertilizers;
- price of chemical fertilizers;
- consumption of traditional fertilizers, etc. are to be considered.

Also, price and distribution of various cooking and illuminating devices form part of this study.

iii) Services

- transport facilities;
- distribution of households according to use of water sources;
- distribution of households according to distance from water source;
- distribution of households according to use of toilets;
- distribution of workshops for repair of devices, etc.

iv) Social aspects

The success of BT depends on its acceptability by the common man. Acceptability studies should consider cultural levels of people, social customs and habits, beliefs, prejudices, educational status etc.

3.53 Inventory of existing biogas plants

Information regarding the following aspects of both existing and intended biogas plants is necessary :

- Location;
- Climatic conditions of the region;
- Sub-soil conditions of the region;
- Model, type and capacity of the plant;
- Operational status;
- Service aspects, the number of family/individuals benefited, types of use made of, characteristics of need etc.(17)

Annexure 2 gives the model of a form for collecting data on existing biogas plants. Studies on similar relevant aspects of other sources of energy and fertiliser used also can be made.

3.6 Selection of priority areas

Any region is a potential area for BT development. However, for practical purposes, certain priority areas can be identified for conducting the studies for overall evaluation, and also for initiating the BT development activities. Priority will be assigned to those areas requiring further evaluation by virtue of their having better potentialities for development and could be done by weighted evaluation criteria. The weights of these criteria will generally be defined by the national development priorities and government policies.

Selection criteria are :

- population to be served;
- type of the economy;
- geographical, climatological and other conditions;
- potential of the area for economic development;
- potential of the area for the appropriate use of energy;
- energy consumption pattern of the area;
- sanitary, health and literacy conditions;
- energy/fertiliser projects in the region (existing proposed);
- availability of resources for BT development;
- possibility of optimum use of biogas and sludge;
- possibility of Integrated Biogas Systems.

The size of smallest such units has to be decided. It could be based on the administrative or revenue divisions of the country, and in cases of grouping such units for programme implementation, parameters like their PHYSICAL PROXIMITY, COMMUNICATION AND TRANSPORTATION FACILITIES, ECONOMIC, SOCIAL AND CULTURAL SIMILARITIES etc. are to be considered.

The different stages of BT development planning and the specific categories of information required for each stage is given in Annexure 3.

Fig. 6 gives a schematic representation of BT Development Programming.

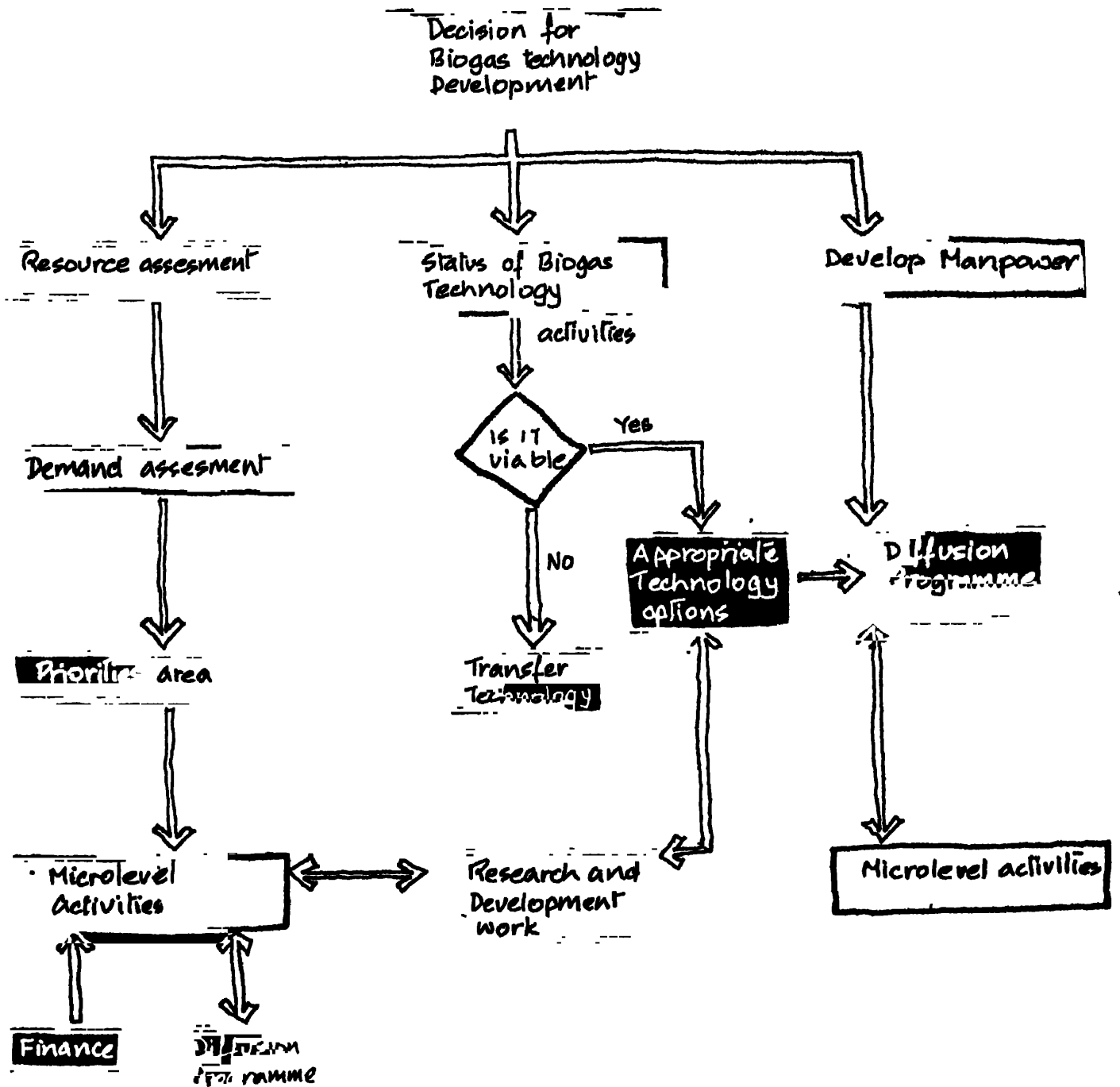



Figure 6 Biogas Technology Development Programme: a schematic representation

Chapter IV   Development of Technological Capabilities

This chapter deals with the technological R&D plans, plan for diffusion of the technology and the manpower development plan as part of the specific plans and programmes to be formulated for BT Development in the country. (12)

4.1 Technological R&D

The objective of BT R&D planning is to tackle the technological, social, economic and other problems in the promotion of the technology in the country. This section gives the parameters for planning and programming the development of technological capabilities.

4.11 R&D policy formulation

The formulation of BT R&D policy is dependent on the following :

- status of the technological know-how available in the country;
- technical and economic viability of the available know-how;
- institutional, human and other resources available in the country; and
- the priority attached to BT in the national energy/fertiliser mix.

4.12 R&D System Development

Factors for consideration

BT research demands expertise from different disciplines like microbiology, social sciences etc. (9) The probable areas of research and the disciplines they belong to are shown below :

Disciplines contributing to BT

Research area	Disciplines
Fermentation mechanism	Microbiology, biochemistry
Fermentation reaction kinetics	Chemical engineering
Design of digester	Civil and mechanical engineering
Construction materials	Chemical and civil engineering
Construction techniques	Civil and mechanical engineering
Use of gas and sludge	Chemical, mechanical and electrical engineering, agriculture, soil chemistry
Pollution effect	Chemical engineering. Public health
Socio-economic evaluation	Social sciences

The results of socio-economic research is mostly location-specific; and both technological and socio-economic research influence each other. R&D system development programme thus should aim at

- identifying and developing the required expertise and capability in these various fields;
- devising national and regional level research and development schemes oriented to the needs of the country/region;
- coordination of research in the different levels;
- arranging to develop/produce plant parts and utilisation devices;
- arranging to have proper interaction with the beneficiaries, manufacturers, etc. and
- dissemination of research results by means of manuals and similar publications.

4.13 Programme formulation

The specific R&D programmes should cover the following :

- assessment of the technological capability of the country for implementing the BT Development Plans
- if need be, arranging to transfer BT from other countries
- adapting and innovating the technology available/ borrowed to suit the specific conditions of the country
- assessment of institutional capacity of the nation for carrying out R&D
- estimating the human resources potential of the nation for formulating R&D manpower plan
- identifying specific areas of R&D most suited to the country
- preparing guidelines for establishing liaison between the R&D institutes and the beneficiaries on the one hand and the manufacturers of equipments and devices on the other
- preparing guidelines for the establishment of BT Information Centre for dissemination of information.
- devicing methods for project monitoring: guidelines for maintaining a record of all aspects of the projects like the project duration, utilization of funds, results obtained etc. as well as bringing out periodical reports stating all the positive and negative aspects of the project
- formulating a sound financial policy for ensuring steady funding of research projects and
- setting up a national body to coordinate, supervise and monitor the R&D projects.

4.14 Operational Procedures for the programme

a) Identification of resources

Both the institutional and human resources are to be considered. Assessment of institutional capacity of the nation would include an inventory of universities, energy and rural development research institutes, environmental studies centres, industrial concerns etc.

An inventory of the national expertise available in the country should be taken. This includes R&D personnel working in the different disciplines contributing to the development of BT. Generally this expertise would be scattered in the respective departments or research institutions of the concerned disciplines/areas of specialisation. The ideal situation would be to have at least one institution specialising in all the subjects contributing to BT.

A project team representing R&D expertise from the various disciplines/areas of specialisation can then be constituted.

b) Technology transfer

Transfer of technology depends on several factors especially the country's capability for generation, development and implementation of the technology.

The need for BT transfer from one country to another may arise due to any of the following two factors :

- the country is characterised by lack of BT R&D efforts; or
- the available knowledge/method is not appropriate to the country, and a better model/method may have to be developed.

The important areas of transfer are the technology of plant construction and operation and that of utilisation devices. Mode of transfer would start from exchanging information and subsequently leading to spot visits to successful plants in the country and imparting the technology by means of on-site advice as also helping in plant installation and operation etc.

The technology thus obtained should however be tested in relation to its applicability in the geographical, climatic, social and other conditions of the recipient country. The plant model has to be tested at the laboratory scale to study its suitability or otherwise for the country, the modifications to be made to render it appropriate for the country or different regions of the country.

c) Technolo ical options

BT is essentially location-specific and hence the technological alternatives suited for any one country cannot be listed out categorically. The specific goals of R&D units in a country would be dictated by its geographical, socio-economic and other characteristics.

However, a broad list of potential areas demanding attention by R&D units are given below with a view to pointing out the magnitude and diversity of areas for investigation. (11, 21)

Technological research

Areas of research	Specific problems
Hardware	
1. Plant designs	Design/models suited for the nation, adaptation or modification of designs, standardisation etc.
2. Plant construction	Various materials /combination of materials for construction, properties and problems of these materials, developing alternate, cheap, locally available construction materials, construction techniques, standards, specifications and commercialisation of production etc.
3. Utilisation devices	
a) Cooking devices	Design of biogas stoves, variety, properties, specifications etc. of stoves, indigenous stove models, adapting existing stoves etc.
b) Lighting devices	Commercially made and local models of lamps, properties, gas pressure, efficiency, etc. method of use directly or after conversion to electrical energy, conversion engines etc.

Areas of research	Specific problems
c) Other devices	Biogas engines - design, performance etc. Biogas storage and transportation system.
Software	
1. Input materials	Types of local materials suitable, gas yield, quality of gas produced etc.
2. Fermentation	Theory of fermentation, agents, chemical reactions, retention period, fermentation conditions, effect of digester designs on fermentation etc.
3. Output	Biogas - properties and applications Sludge - conditioning, applications etc.

Socioeconomic research

Main elements for consideration are :

- the availability of input materials,
- agricultural, sanitational, environmental and other impact on society,
- cost-benefit analysis of biogas plants
- economic, social and political problems in promotion,
- commercial production, marketing, etc. of plant parts and utilisation devices.

4.15 Coordination of R&D efforts

The research activities will generally be going on in the different regions of the country. However, a national coordinating body consisting of :

- Biogas technology experts,
- Administrators,
- Project managers, etc. can be constituted.

This body can be in charge of identifying and promoting BT research areas of immediate relevance to the country. Coordinating the R&D work going on in the country

- preparing standards and specifications for plant parts, utilisation devices, etc.
- preparing guidelines for liaison with the beneficiaries, extension workers, manufacturers of equipments, etc.
- project monitoring
- providing consultation and technical enquiry services etc.

4.16 Financin

The R&D financial plan is intended to ensure a steady flow of fund for the on-going research projects. The plan should decide upon

- priority to be attached to plan various BT R&D projects
- the number of projects to be sanctioned
- financial commitment of each of the projects
- time, and mode of release of funds
- sources of finance etc.

A schematic representation of biogas technological capability development in a country is shown in Fig. 7.

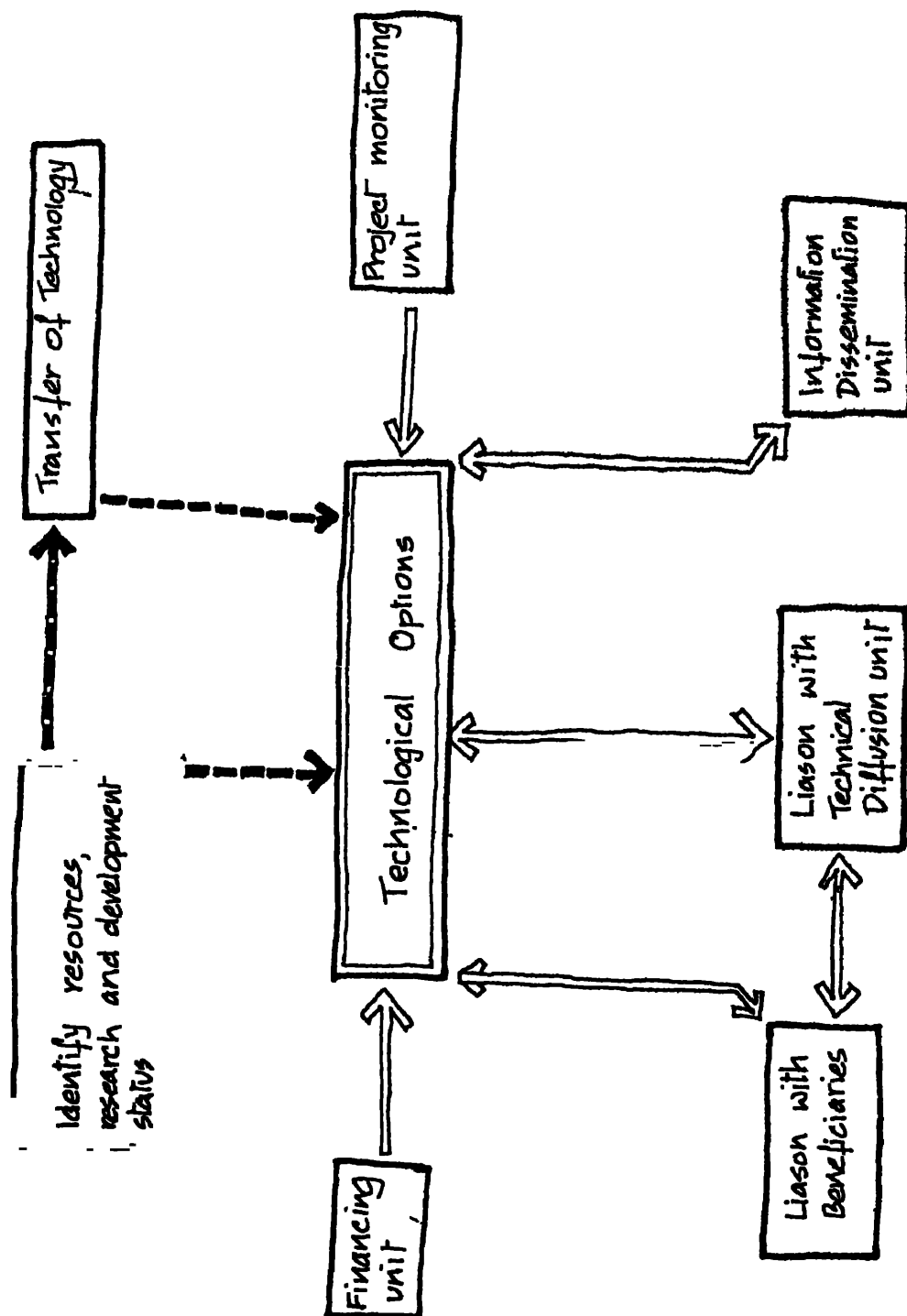



Fig 7 Development of Technological Capabilities

4.2 Diffusion of technology

This section gives the formulation of a well-defined plan and associated programmes for reaching BT to its actual beneficiaries. Fig. 8 gives the organisational structure of BT diffusion.

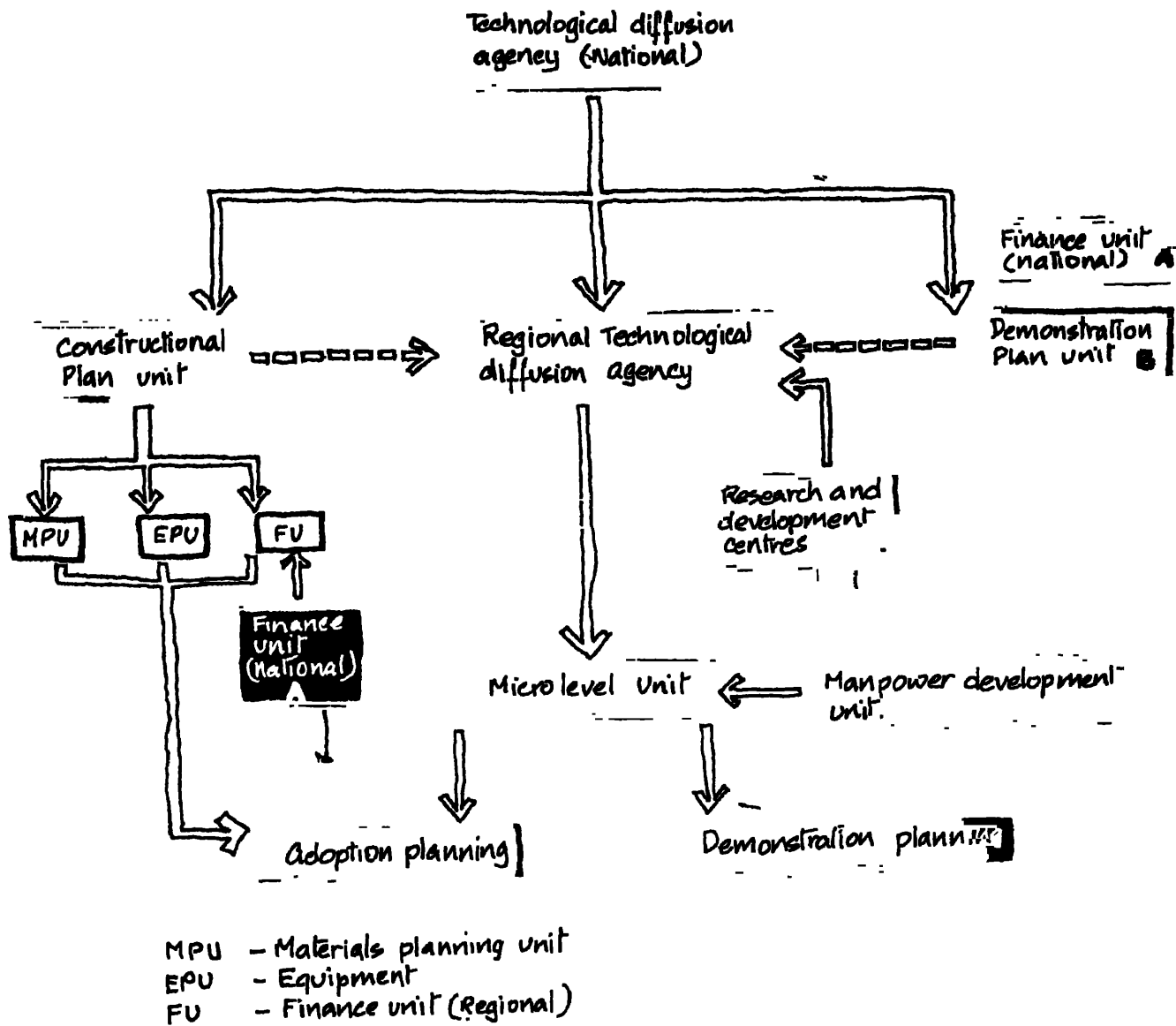



Figure 8 Technological Diffusion : Organisational Structure.

The basic assumption for the formulation of BT diffusion plan are as follows :

- the technology is acceptable both at the national level and at the local and individual levels;
- the adoption of the technology is not a temporary phenomenon: BT is to be integrated into the social and economic fabric of the village/community where it is introduced;
- there is a chain effect of technology adoption. The diffusion policy should give the necessary impetus to INITIATE AND SUSTAIN THIS CHAIN REACTION of the spread of the technology from one household to the other. (22)

4.21 Acceptability study

The acceptability of BT has to be considered from two levels: the macro or the national level and the micro or the area level.

National level acceptability is decided only after comparing the system with other priority projects in terms of regional development, rural, industrial development and other national development policies of the country, and technical and economic feasibility of BT. National level acceptability is established before a policy decision to go ahead with BT Development is taken.

The micro-level or the individual level acceptability is decided by several factors. In general, user level acceptability is defined by opportunity cost.

Over and above the merits and demerits of the system mentioned in Chapter II, micro level acceptability study should take into consideration the following aspects :

- other competitive energy sources in practice in the area e.g. commercial sources like kerosene, electricity, non-commercial sources like dung, firewood etc.
- economic feasibility defined by :
    - cash-flow analysis;
    - opportunity cost;
    - input supply;
    - facilities for financial asssitance;
    - purchasing power of the people etc.;

- social factors like
  - desire for convenience;
  - socio-cultural and religious acceptance;
- environmental and health factors like
  - direct impact;
  - indirect impact;
- technological feasibility defined by
  - production;
  - storage;
  - use of output etc.

4.22 Demonstration programme

Assuming acceptability of BT at the national and micro-levels, based on study conducted, the next step is to diffuse the technology among the actual beneficiaries. This is necessitated due to the fact that

- the role of human element in the success of BT is more than in any other technology
- individual level acceptability is often limited by several social, economic and religious constraints.

One of the methods for diffusion of the technology is by setting up demonstration plants. For this purpose, one should take the following factors into consideration :

- selection of areas for setting up demonstration plants (this could be a unit under the priority areas selected (Chapter III). The size of the smallest such unit has to be decided;
- choice of size, model etc. of demonstration plants;
- number of plants in each area of demonstration;
- cost of each demonstration plant;
- approximate period for completion of the project;
- sources of finance;
- source of other resources (manpower, etc.); and
- agency for taking up the project. (It could be a unit under the BT Development Planning Unit with regional local authorities under it or independent regional/ local agencies).

The implementation of specific demonstration projects is given in Chapter V.

The basic assumption for the formulation of BT diffusion plan are as follows :

- the technology is acceptable both at the national level and at the local and individual levels;
- the adoption of the technology is not a temporary phenomenon; BT is to be integrated into the social and economic fabric of the village/community where it is introduced;
- there is a chain effect of technology adoption. The diffusion policy should give the necessary impetus to INITIATE AND SUSTAIN THIS CHAIN REACTION of the spread of the technology from one household to the other. (22)

4.21 Acceptability study

The acceptability of BT has to be considered from two levels: the macro or the national level and the micro or the area level.

National level acceptability is decided only after comparing the system with other priority projects in terms of regional development, rural, industrial development and other national development policies of the country, and technical and economic feasibility of BT. National level acceptability is established before a policy decision to go ahead with BT Development is taken.

The micro-level or the individual level acceptability is decided by several factors. In general, user level acceptability is defined by opportunity cost.

Over and above the merits and demerits of the system mentioned in Chapter II, micro level acceptability study should take into consideration the following aspects :

- other competitive energy sources in practice in the area e.g. commercial sources like kerosene, electricity, non-commercial sources like dung, firewood etc.
- economic feasibility defined by :
  - cash-flow analysis;
  - opportunity cost;
  - input supply;
  - facilities for financial assitance;
  - purchasing power of the people etc.;

- institutional facilities for imparting training: existing/ necessary (the training centres can be attached to existing BT R&D centres, Agricultural Extension Training Centres, offices of voluntary agencies, polytechnics etc.)
- financial resources required for training and deployment of the people; and
- agency (national/regional/local) responsible for implementing the Manpower Development Plans.

The organisation structure necessary for manpower development is given in Fig. 9.

Fig 9: Manpower Development: Organisational Structure

The basic assumption for the formulation of BT diffusion plan are as follows :

- the technology is acceptable both at the national level and at the local and individual levels;
- the adoption of the technology is not a temporary phenomenon; BT is to be integrated into the social and economic fabric of the village/community where it is introduced;
- there is a chain effect of technology adoption. The diffusion policy should give the necessary impetus to INITIATE AND SUSTAIN THIS CHAIN REACTION of the spread of the technology from one household to the other. (22)

4.21 Acceptability study

The acceptability of BT has to be considered from two levels: the macro or the national level and the micro or the area level.

National level acceptability is decided only after comparing the system with other priority projects in terms of regional development, rural, industrial development and other national development policies of the country, and technical and economic feasibility of BT. National level acceptability is established before a policy decision to go ahead with BT Development is taken.

The micro-level or the individual level acceptability is decided by several factors. In general, user level acceptability is defined by opportunity cost.

Over and above the merits and demerits of the system mentioned in Chapter II, micro level acceptability study should take into consideration the following aspects :

- other competitive energy sources in practice in the area e.g. commercial sources like kerosene, electricity, non-commercial sources like dung, firewood etc.
- economic feasibility defined by :
  - cash-flow analysis;
  - opportunity cost;
  - input supply;
  - facilities for financial assitance;
  - purchasing power of the people etc.;

- institutional facilities for imparting training: existing/ necessary (the training centres can be attached to existing BT R&D centres, Agricultural Extension Training Centres, offices of voluntary agencies, poly- technics etc.)
- financial resources required for training and deployment of the people; and
- agency (national/regional/local) responsible for implementing the Manpower Development Plans.

The organisation structure necessary for manpower development is given in Fig. 9.

Fig 9: Manpower Development: Organisational Structure

4.32 Extension Training

The programme has to take measures to set up a network of decentralised agencies comprising of suitably trained personnel to take the technology to its beneficiaries, to impart technical know-how to them and to help him in the installation, operation and maintenance of biogas plants.

Extension training programme includes the following :

- identifying national institutions/agencies which have developed (or establishing such institutes/agencies if not available already) the necessary expertise in imparting information and providing training in biogas technology extension;
- identifying the grass-root level agencies with sufficient aptitude and experience in working among the people;
- arranging to impart training in BT extension to these grass-root level agencies (or the extension workers);
- arranging for the proper deployment, coordination and supervision of these agencies;
- identifying the organisational set-up of such training facilities at the national, regional and local levels
- cooperating with the R&D centres, technology diffusion units etc.; and
- making adequate provision for financing the extension training programmes.

Details regarding the subject content, duration, faculty etc. of the extension training programme are given in Annexure 4.

4.33 Construction training

BT being comparatively new, the first step for construction training would be to introduce a mechanism for training the trainers. (10) This training has to be held for the initial few years of starting the project, till a sufficient number of professional local level masons/technicians has been produced. Construction Training Programme includes the following :

- identify the agency/institute for holding the training of trainers. (This could be the national institutes identified in the previous stage, e.g. biogas research institutes, universities/departments of agriculture, energy etc. where BT research is conducted and can be made centres for imparting this training; or it could

be one or more permanent institutions set up exclusively for construction training with the faculty comprising of expertise from the above institutions);
- identify the agency/institute for conducting regular plant construction training courses. This could be attached to the existing extension training centres, gram sevak training centres, etc.
- formulate the curriculum content, duration, etc. of the course;
- establish links with the BT research institutes for ensuring regular flow of new information generated or innovations made;
- make provision for the financial expenditure incurred for the training and deployment. (For details, see Annexure 5)

4.34 Orientation programme

This is with a view to make the development functionaries at various levels aware of the promises, prospects and problems of BT. A programme for conducting orientation courses for regional/local government authorities, agricultural officers, agricultural officers, representatives of banks, national financial organisations, members of the various development authorities, agro-industries corporation, agricultural universities, voluntary agencies etc. has to be drawn up. (10) Details of such a programme is given in Annexure 6.

Chapter V Micro-level Planning

The question of planning specific projects at the micro-level is relevant only in the context of a decision favouring the adoption of BT at the national level. Micro-level decision making in the case of BT involves two types of people :

a) The local development functionary. This could be a single extension worker or a group of people entrusted with the local level BT development.

b) The individual householder owning a biogas plant.

5.1 Factors for Consideration

- the micro-level agency for the local development functionary will be the nodal point or the region and hence will be responsible for :
  - promotion of the technology in the region;
  - coordinating and motivating the plant owners;
  - cooperating with other units of BT Development like the Regional Demonstration Plan Unit, Construction Plan Units, R&D Centres etc.;
  - arranging to develop construction skills, utilisation devices production skills, etc. for the area;
  - arranging to realise all the financial facilities offered for the area etc.

5.2 Resources and demand assessment at the micro-level

Micro-level planning involves the assessment of the resources and energy demands for the specific area or the household in question. The information requirements for micro-level planning are similar to the national level plan.

- General information of the area like number and size of households, average income per household, average number of cattle, pig etc. per household, man-cattle ratio, occupational pattern, size and distribution of land, area under cultivation, configuration and density of households in the area etc.

- the type and quantity of construction materials and other resources available;
- present energy consumption pattern, likely future demand for fuel and fertiliser, price, availability etc. of these sources;
- geographical, climatological and other characteristics of the region;
- social factors like stratification, cultural levels, entrepreneurial ability, social habits of the people etc. are to be collected, for the area as such by the concerned local development functionary at the micro-level and by the household owner at the household level.

Annexure 7 gives the decision making stages and their information requirements at the micro-level.

5.3 Policy options

Two major policy options at the micro-level are whether to go for family plants, or community plants.

From the managerial point of view, the essential difference between these two options is that :

- in the case of the former, decision regarding input collection, use, distribution of output etc. is taken by a single authority, whereas in the latter it depends on all the participating families of the community;
- also, the output is used internally, (i.e. by the members of the family only) in family plants as against the sharing of output in the case of community plants.

A decision in favour of any one of these options should be preceded by a consideration of their merits and defects.

A comparison of the options

Options	Advantages	Disadvantages
Family plants	Easy to manage.	a) May not be able to afford the investment. b) Very few households may be able to mobilise adequate input materials.
Community plants	Economy of scale on construction and generation possible. Economies of effort and individual managerial ability possible.	a) High labour cost for collection of input materials. b) Distribution costs increase as the command area increases.

5.31 Selection parameters

Following are the basic parameters for consideration in the selection of community plants. (7)

- the existence of a social community with neighbourhood plants where mostly 2 or 3 families participate;
- the community is already organised or can be organised for controlling the sustained operation and maintenance of the plant;
- the chances of utilising the farm waste from smaller holdings of the region which would otherwise be wasted/underutilized;
- the chances of the public, including economically weaker sections, at large being benefited from the outputs is more;
- possibility of using the energy generated in some small scale industry for the village/region;
- chances of evolving proper guidelines for social management of the plant exists.

A cost benefit analysis of the options considering

- Direct costs
  - Capital cost for civil construction, gas holder, pipes, appliances, cost of land, etc.
  - Operating cost like cost of input, labour cost (including managerial expenses), distribution costs, maintenance costs, etc. and

  Indirect costs
  - Depriving the poor people of inputs like cowdung;
  - Management problem, etc. as against the direct and indirect benefits of plants is to be conducted.

If the primary evaluation of these parameters for a region goes against these, family size plants are to be opted.

5.4 Operational scheme

For proper functioning of community plants an operational scheme has to be formulated. The scheme should take into consideration the following points : (13,15)

- setting up a village level authority for the management of community plants. This authority may consist of the local development functionaries, bank officials, local community leaders, participating households, authorities of voluntary organisations, public institutions etc.;
- evolving a mechanism for the daily purchase of input materials from the farmers;
- the pricing policy of these inputs and outputs should be evolved taking into consideration the economic conditions existing in the village/region. The basic objective of the policy should be to get maximum participation from all sections of the community and thus should be oriented towards a favourable one for the poorer people. Pricing policy would depend on factors like
  - market price of dung (used directly as fuel and fertiliser);
  - price of alternate sources of fuel in use;
  - price of chemical fertilizers;
  - the average expenditure of households on fuel and fertilizer etc.

- evolving a mechanism for the operation of the plant with a view to provide employment for the weaker section of the community;
- evolving policies for making optimum use of the by-products, including proper distribution of the gas and fertilizer;
- providing cheaper facilities like community kitchens for those who cannot afford to buy gas.

5.5 Construction and maintenance

The role of the development functionary at this stage is limited to helping the individual (family plant) or the management (community plants) installing a biogas plant to make proper decisions on the following :

- checking the suitability of the model selected;
- selecting the appropriate size and site for the plant;
- assess construction materials to be acquired (type, quantity);
- price of construction materials;
- concessions/subsidies etc. if available for construction materials;
- labour availability (number, type, etc.)
- availability of plant parts, utilisation devices;
- precautions to be taken - pretreatment of the plants, checking for cracks, leaks, etc.
- input preparation: slurry consistency, frequency of feeding, time lag, between first filling and the regular feeding of slurry;
- start up and operation of the plant;
- use of outputs: types and mode of use; devices needed;
- maintenance: precautions against scum formation, periodical repair/replacement of plant parts, utilisation devices;
- financing: sources, methods of getting assistance, eligibility, repayment period and other condition for financial assistance.

Annexure 8 gives an illustration of the decision making points and specific calculations involved at the individual level.

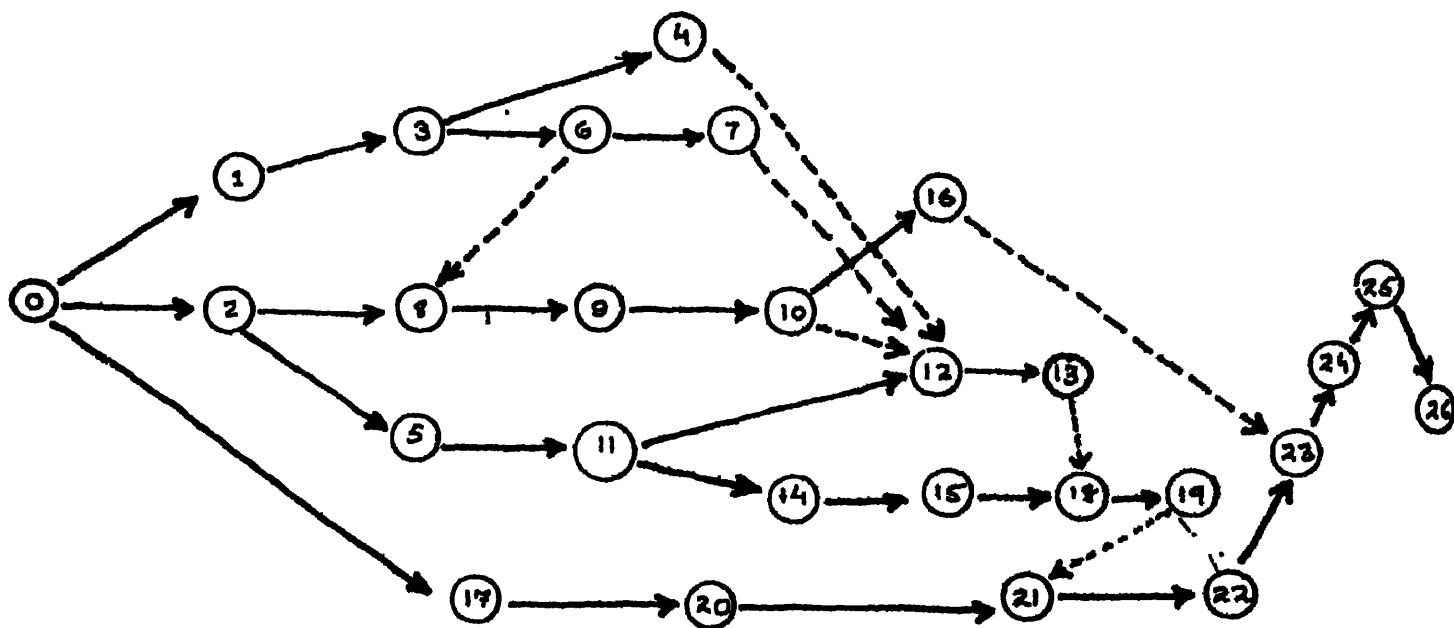
The local development functionary, however, can draw up a programme considering the broad outlines of construction work, for the plant model selected for the area. This should identify the different phases of construction, possible unforseen developments regarding technological, managerial or other aspects of construction and maintenance etc. (Fig. 10)

0. Start (Decision to install a Biogas Plant)
1. Select Model
2. Decide upon the Size
3. Assess construction materials needed
4. Order/prepare construction materials
5. Locate Plant site
6. Assess no. and type of labour needed
7. Get the Labour
8. Assess Financial requirements
9. Explore sources of Financial assistance
10. Get necessary finance
11. Preconstruction examination of soil
12. Construct the Digester
13. Construct inlet and outlet tanks
14. Construct Gas Holder
15. Connect the Gas pipes
16. Purchase utilisation devices
17. Collect input materials for 1st Filling
18. Check for leaks, cracks etc.
19. Pretreatment of the Digester
20. Prepare slurry for 1st Filling
21. Fill the digester with slurry and starter
22. Fix the Gas Holder
23. Connect utilisation devices
24. Remove air from Gas Holder and devices
25. Start feeding the slurry daily
26. Start using the Gas produced

Figure 10 Biogas Plant Installation flow chart

The possible amount of community contribution (in the form of supervisory/skilled manpower, substrates, construction materials and other services) has also to be assessed. This is applicable in the case of a community plant, and these factors depend, to a great extent, on the socio-economic, political and other conditions prevailing in the region. Hence the cooperation of community leaders, social organisations/associations, officials of the regional cooperative organisations etc. is to be sought in order to mobilize the necessary support for the project.

The programme should also consider specifications of size, method of plant construction, diameter, thickness etc. of gas holder, inlet/outlet pipes etc; because following these specification is essential for the proper functioning of the plant. Also all work-related responsibilities are to be clearly defined.

The manpower needed for construction work are preferably skilled labourers trained in biogas plant construction and operation. In case of community plants a supervisor may also be necessary. The construction personnel may either be recruited directly by the authority or the whole construction work can be entrusted with a contractor who has a team of skilled labourers.

A schematic representation of the activities involved at the micro-level is given in Fig. 11.

5.6 Summing up

In general, micro-level planning needs careful study of the peculiarities of the region in question and hence needs to be treated individually. On optimum techno-economic grounds alone the number and type of plants would vary from village to village depending on its configuration. Most often, a nation would have a mix of :

- family plants (in affluent agricultural economies);
- community plants (in economically less developed areas) and
- large scale plants (in industrial concerns etc.) working simultaneously.

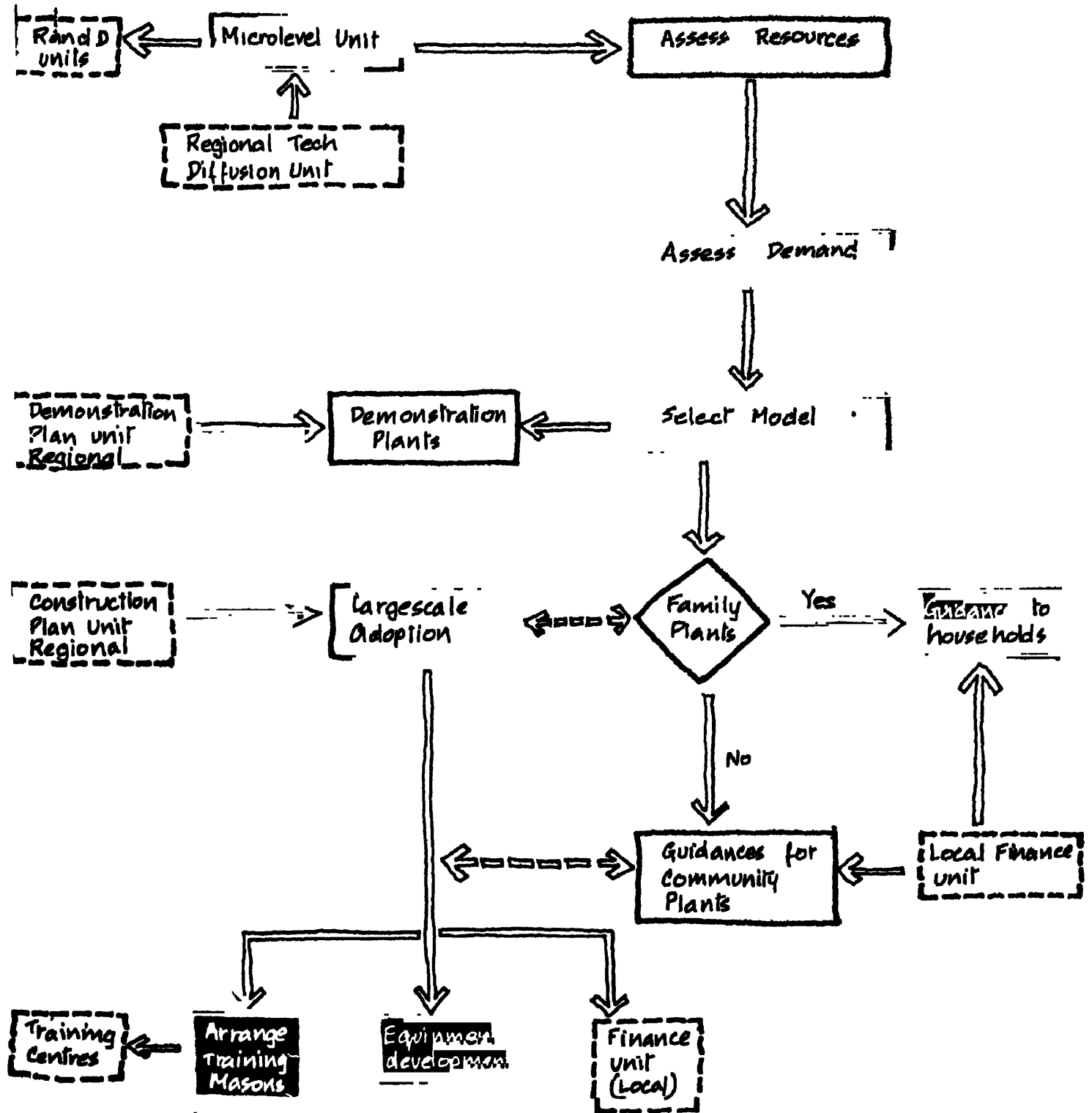



Fig 11 Microlevel Planning: A schematic Presentation

Chapter VI Financing

6.1 Preamble

This chapter identifies problems encountered and their financial implications in financing investments for BT development. The problems encountered are :

At the individual level,

- Biogas system involves high capital investment for majority of the rural farmers;
- inadequate economic capability of the beneficiaries for repayment of loans advanced.

At the national level,

- Lack of proper estimation of potential community contribution in terms of manpower and materials;
- lack of proper coordination between financing institutions;
- lack of sound investment criteria by financing agencies;
- absence of well founded national BT financing policy.

6.2 Financial plan

Certain guidelines for evolving financial plan for BT development are given below (12)

- Reduce initial investment by selecting appropriate models and sizes of the plant, local production of construction materials and equipments, community participation in construction work etc.;
- efficient planning and organising of demonstration units to have minimum investment at this stage;
- evolve proper investment criteria considering the national benefits of BT and the differential capacity of beneficiaries for repayment;
- evolve proper mechanism for financing non-recoverable investments;
- evolve a uniform network of financing institutions/agencies in the country incorporating government departments, banks, voluntary associations etc.;
- if necessary, explore the possibilities of getting external financial assistance.

It is emphasised here that special efforts should be made for reducing investment costs. Some of the methods that can be considered for this are :

- conducting overall evaluation of resources and demand on an area/locality basis to achieve economy of scale;
- implementing demonstration projects for a group of similar areas/localities;
- preparing documents like handbooks, manuals, etc. on the plant models, guidelines for resource evaluation studies, etc. :
- standardising equipments, plant sizes, etc. ;
- standardising construction works;
- promoting community participation; and
- as far as possible, relying on indigenous technology.

6.3 BT financing

Financing BT development can be organised at international, national and local levels.

a) International

Financial assistance in the form of grant, aid etc. from international associations /agencies, inter-governmental and non-governmental institutions, associations, etc.

b) National

National financial assistance would be of three categories (10, 18)

- Budgetary contribution of the country (central or regional governments) may be provided as subsidy portion of the capital cost of biogas plant to beneficiaries, manufacturers of utilisation devices, etc.
- institutional finance generally given as loans;
- other items of expenditure falling under heads like organisational staff support, training both in construction and maintenance, orientation and demonstration programmes, etc.

Proportion of the first two types of sources is to be decided periodically by the country in question. The National BT Development Agency or a National Financing Agency may be made responsible for the appropriation of the subsidies to different regions. Norms for fixing subsidy can be either

- percentage basis, i.e. giving a definite percentage of the total plant cost as subsidy; or
- fixed amount basis, i.e. depending on the category of plants.

For advancing loans, a national body may have to be identified or it could be the National Financing Agency itself. This is mainly for establishing the bankability of the project by various commercial bank and other financial institutions, especially in the wake of the benefits of BT being notional. Also, uniform lending procedures, terms and conditions for operating a loan, investment recovery criteria etc. for the various financial institutions under the national body are to be formulated.

c) Local

Contributions from the community could be in the form of construction materials, labour, land, etc. or even as subsidy from local voluntary agencies or associations.

In any case, it is always better to estimate the amount of possible community contribution since it also forms part of the total investment.

However, the above categories of assistance are only for the financial commitment likely to be incurred in the installation of the plant. The operation and maintenance costs are to be borne by the beneficiaries concerned.

6.4 Recovery of assistance

Depending on the capability of the country to finance the programme, a portion of the financial assistance offered can be recovered. This has to be carefully planned in terms of the capability of the prospective plant owner for repayment.

Financial recovery plan should consider the following :

- rate of interest to be fixed;
- pay-back period to be offered;
- eligibility criteria of the householder;
- special provision for householder of the lower strata, if any, etc.

Chapter VII International Cooperation

7.1 Need for cooperation

A concerted effort on the part of all national and international development agencies/organisations for the development of BT is necessitated due to the following factors :

- BT offers a source of non-conventional, renewable, decentralised energy;
- large scale adoption of the technology demands conscious efforts for making it acceptable to the people;
- although of use to all the nations in the wake of energy crisis and lack of sanitation, this technology is highly relevant for developing countries being multidisciplinary in nature, the
- technology needs expertise from different disciplines all of which a nation may not have.

7.2 Levels of cooperation

Cooperation can be in different levels and in the various spheres of BT development activities.

- Bilateral (between 2 interested countries)
- Regional (among several countries of a region)
- Global

7.3 Areas of activity

a) Technical assistance

- a global project incorporating mobilisation of existing technology and its transfer to interested countries may be considered;
- initiating integrated industrial, engineering and applied research activities as also methods for adaptation, development and utilization on a package basis;
- organising regional studies on the different models, and sizes of plants, especially community plants for evolving solutions to problems relating to substrate collection, distribution of output price fixing etc.;
- establishing pilot/demonstration projects at the regional level;
- establishing integrated farming systems for making integrated use of the products;
- providing the necessary expertise to countries planning to adopt BT.

b) Manpower development

- Assisting prospective nations to send their decision makers, including experts, institutional heads, administrative staff etc. for visiting countries where biogas programmes have made considerable progress;
- assisting nations in developing a cadre of technically trained personnel for research, development and adaptation of the technology.

c) Financial assistance

- Device methods for providing financial assistance for all programmes directed towards developing institutional infrastructure, establishing demonstration plants, initiating integrated research and development etc.

d) Information dissemination

- Organising programmes for the exchange of equipments, films, audio-visual aids, etc. dealing with different aspects of BT;
- to set up a BT Information Centre for the collection and dissemination of existing information on technical and other aspects of BT;
- to set up programmes for preparing manuals, handbooks, etc. for dissemination;
- to arrange for conducting workshops, symposia etc. at the different levels at reasonable intervals on matters related to the development and utilisation of BT.

7.4 Agencies

International organisations like Economic and Social Council, Regional Economic Commission of UN, specialised agencies like Unesco, FAO, WHO, etc., and various non-governmental organisations are involved in the promotion of BT. (4) The various agencies and the spheres of their activity are given below.

International Agencies Involved in BT Development

Agencies	Areas & Remarks	Cooperating Organisations
Food & Agricultural Organisation (FAO)	Exploration and production: Promotion of technology for biogas production from wastes and residues and use of effluents as fertilizers.	UNEP, UNIDO, ESCAP, UNDP, SIDA
United Nations Development Fund (UNDP)	Technical cooperation and demonstration of biogas and allied technologies in the People's Democratic Republic of Yemen, Lesotho, Philippines, Tanzania.	UNESCO, UNIDO
United Nations Environmental Programme (UNEP)	Utilization of BT for environmental management; rural energy centres in Mexico, Senegal and Sri Lanka; integrated systems.	
United Nations Educational, Scientific and Cultural Organisation (UNESCO)	Regional Workshops and demonstration projects in biomass conversion into fuel in Brazil and Uruguay.	
	Expert meeting on use of biogas.	BCSIR
	Special Symposium "Biofuels and Bio-fertilizers," Lagos, Nigeria, 1980.	UNEP, CFTC, OAU
United Nations Children's Fund (UNICEF)	Provision of basic services to children via village and rural biogas systems.	

Agencies	Areas & Remarks	Cooperating Organisations
United Nations University (UNU)	Programme on bio-conversion of organic residues for rural development through biomass and biogas production (Tanzania, China)	UNESCO, FAO
Commission of the European Communities (EEC)	High-level research programmes in microbial fermentation to Ethanol and Biogas.	
International Development Bank (IDB)	Intermediate technology programme on fuel production from agricultural and animal wastes for Central America.	
International Development Research Centre (IDRC)	Support of research projects; social and economic evaluation of BT.	

A global project incorporating all the aspects of BT with regional focal points for coordinating biogas projects can be formulated.

Annexure 1 Variations of Flexible Gas Holder Model

Variation	Advantages	Disadvantages	Name of Model	Comments
1. Mild steel gas holder supported by central guide pipe fixed to the digester.	Guide pipe acts as an effective scum breaking mechanism.	Mild steel may be costly; the gas holder gets corroded unless repainted periodically.	Indian Model.	Both vertical and horizontal designs to suit different geographical locations developed.
2. An underground fixed pipe is attached to the central guidepost, piping gas through the guide pipe rather than through a flexible hose on the gas holder roof.	Gas pressure and volume will not be affected by rotating the gas holder for scum breaking which hence can be done even when the gas is being used.	Supply of gas has to be adjusted away from the gas holder.	Nepalese Model. (Development and consulting services, Butwal).	Straight and tapering designs available to suit different geographical locations.
3. Gas holder made of mild steel. The sides of the gas holder are extended to form a solar water heater and solar still. Retention time has been reduced to 35 days.	Optimum slurry temperature can be maintained even during winter season. Less retention time means less volume and thus less construction cost.	This facility may not be necessary during summer in tropical countries.	ASTRA Model.	This model has yet to be tested in actual situations.
4. A ferrocement gas holder. 3 mild steel bars inserted at the top and bottom of the gas holder wall placed radially and connected by vertical bars serves as scum breaking mechanism.	Ferrocement gas holder is non-corrosive, and hence the plant needs less maintenance cost. Scum braking possible by rotating the gas holder.	Ferrocement is porous. The gas holder hence has to be coated on inside and outside by resin-based coatings or polyurethene coatings. Gas holder will be very heavy as their scale increases; also it has to be cured before installation.	SERC Model.	Suited for small family plants.

Variation	Advantages	Disadvantages	Name of Model	Comments
5. Double-walled digester. Steel gas holder floating between two walls containing water topped with oil to prevent evaporation. A settling chamber is attached.	Double walling gives cleaner-less messy operation. Water seal prevents the gas from escaping. The supernatent liquid settles in the settling chamber. This increases the quality of the sludge. RT is only 1 day.	Cost of construction is high; double walling makes repair and maintenance difficult.	Taiwanese Model.	Fermentation conditions are less critical in this. (including stirring). Model is suited for Integrated Biogas Systems.
6. The gas holder floats on a water column topped with oil film.	Reduced corrosion of gas holder, particularly if the oil film is maintained. Eliminates any smell generally produced in gas plants using human excreta.	It is more expensive. Maintaining water seal and oil film may be an additional operation. Scum breaking is difficult as radial struts cannot be attached to the sides of the gas holder.	Pakistan.	
7. A cluster of digesters built above ground (as many as the number of days of retention time plus one). The digesters are all connected to a separate steel gas holder.	The sludge is drained out through outlet pipes and fibrous material removed through side manholes.	Steel gas holder may be expensive.	Maya Farms Model (Philippines).	Suited for large scale application.

Variations	Advantages	Disadvantages	Name of Model	Comments
Brick digester with low density polyethelene gasholder supported by a geodesic dome. The dome is bolted to the digester walls and the gas holder is retained by a water seal.	The gas holder is portable, it does not need any regular maintenance. Plant is considerably cheaper than the floating gas holder model and the Janata dome type plant. Stirring is made possible by a stirrer passing through a guide tube.	Fixing the gas pipes and stirrer with the gas holder is difficult and needs great care.	Jwala Model of MCRC, India.	This combines the merits of KVIC type in the sense that it can be run on a continuous feeding basis. At the same time the geodesic dome helps to control the pressure inside the gas holder and to hold the LDPE balloon in position.

Annexure 1 Fixed Dome Model Variations

Variations	Advantages	Disadvantages	Name of Model	Comments
1. Completely underground plant. The sides of the digester are extended upwards to form a fixed dome shaped gas holder.	Any locally available material can be used for construction and is hence cheap. Temperature can be maintained more or less stable.	Construction needs special skills. Stirring is difficult in large plants. The sludge has to be taken out by buckets through the manhole fitted on top of the dome. Gas pressure control is difficult.	Chinese Model (Szechuan Province).	Mainly used for batch feeding process, and hence agricultural crop residues, plant wastes etc. can be used.
2. Basically a Chinese design, but uses mainly bricks and cement. The inlet and outlet pipes reach the bottom of the digester and open out at ground level. There is no manhole on the dome.	Comparatively cheaper model. Construction possible with local materials. Sludge removal is by automatic flow method.	Scum breaking is generally difficult, that too in big plants. Also plant construction requires special skill.	Janata Model.	Suited for continuous operation.
3. A neoprene rubber bag acts as the digester, settling tank and the gas holder. The bag has to be supported upto the level of liquid slurry in it. This is done by placing the bag in a hole dug on the ground upto this level.	Neoprene bag is portable and convenient.	Maintenance and repair of the bag is difficult.	Bag Digester. (Taiwanese Model).	A modification of this using reinforced concrete instead of rubber bag is available now.

placing the bag in a pit
dug on the ground upto this
level

Variations	Advantages	Disadvantages	Name of Model	Comments
Both the digester and gas holder made of red mud plastic - a mixture of red mud, PVC, plasticizer, stabilizer etc.	Easy to manufacture, and transport. Durable since RMP is resistant to UV rays, H_2S, strong alkali etc. No stirring needed because the scum settles to the bottom of the digester.		RMP (Taiwanese Model).	
Fixed dome digester with separate gas holder made of bamboo cement.	Digester is easy to construct since it is not subjected to much pressure. Constant gas pressure can be maintained and hence the utilisation devices can be put to optimum use.	Additional work and cost in building the gas holder and the sludge displacement tank.	Chengdu Model (China).	This model is not yet tested widely.

NNEXURE 2

Form for collecting data on existing biogas plant

Proforma for the Inventory of Biogas Plants in the Village of ______________

in District ______________ State of ______________

---

1. Household Identification No.
2. Name of the household owner
3. No. of dependent members
4. Details of household members

Age	Sex	Education	Occupation

5. Landed property possessed
6. Land under cultivation
7. Details of cultivation (including vegetable/cash crops)

Name of crop	No. of crops/year	Quantity produced	
		Crops	Straws

8. Average annual income for the household
9. Sources of income (Give the amount received)

   Agricultural
   Non agricultural

10. Cattle population

Type of cattlehead	No.	Type of use

11. Type and quantity of cattlefeed needed per year

12. Stabling habits of the cattle
    - always stabled
    - grazing during daytime
    - not stabled at all
    - others

13. Materials possessed by the household
    - domestic appliances like stoves/radio/TV/others (specify)
    - agricultural equipments like tractors/threshers/others (specify)

14. Source of water
    i) consumption
    ii) irrigation

15. Distance from water source

16. Average monthly expenditure

17. Average monthly expenditure for energy
    firewood
    charcoal
    kerosene
    electricity
    others (specify)

18. Fertiliser usage : (a) Dung and other wastes available is sufficient
    (b) Fertiliser has to be purchased to supplement

19. Average annual expenditure on fertiliser
    Dung
    Chemicals

20. Model and size of biogas plant installed

21. Date and cost of installation
    Date Cost

22. Reasons for installing the plant

- prompted by officials/radio/books YES/NO
- seen other plants in operation YES/NO
- to save fuel or fertiliser YES/NO
- only to demonstrate to others YES/NO
- it was a learning experience YES/NO
- others (please specify)

23. Quantity of input materials used per day

- Only dung
- Dung and human excreta
- Dung, human excreta and agricultural wastes

24. Quantity of biogas produced/day

25. Type of use of biogas

Cooking/Lighting/Others/Not used

26. Mode of using the sludge

Liquid/Dried/Composted/Not used

27. Present operational status

In operation/Not working

28. If not working period for which the plant worked

29. Operational problems developed (please specify)

30. Were the problems solved ? YES/NO

31. Cost of maintenance/repair needed

32. Did the officials visit the plant sites ?

- very regularly
- not frequently
- did not come at all

33. Reasons for abandoning the plant
- high cost of maintenance
- lack of technical knowledge
- input was not available
- water is not available
- low efficiency of the plant
- problem with 1st filling
- dislike to use biogas for cooking

34. Was there any saving in the energy/fertiliser expenditure ?

YES/NO

35. If YES, give the type of fuel/fertiliser saved and amount per year

36. Are you happy to have biogas plant in the household ?

YES/NO

37. What is your opinion about biogas plant ?
- very useful
- moderately useful
- not useful

Annexure 3 Decision Making Points and the Corresponding Categories of Information Required for the National Level BT Development Plan

Decision making Stages	Major Decisions to be Made	Types of Information	Specific categories of Information Needed	Remarks
I. Energy/Fertiliser requirements of the nation	1. What BT can do to the nation and individuals ?	Technological	- to provide energy for cooking/lighting/ running engines; - to provide fertiliser for crops; - to provide animal feeds;	This is to get a preliminary understanding, of the potentials of BT.
		"	- to improve environmental conditions of the nation;	
		"	- to help in sanitational and health improvement of the people etc. (prospects/ problems of BT in all these aspects)	
	2. Does the existing energy/fertiliser/ environment situation of the nation warrant the above uses of BT ?	Economic	- energy requirements of the nation (present and future); - present and future sources of energy for the nation; - energy consumption pattern;	
		"	- fertiliser requirements of the nation; - present and future sources of fertiliser for the nation;	
		"	- existing/intended waste disposal facilities in the rural areas.	

Decision making Stages	Major Decisions to be Made	Types of Information	Specific categories of Information Needed	Remarks
II. BT potential in the country	3. Does the nation have enough input materials for adoption of BT ?	Economic	- cattle dung; agricultural wastes, industrial waste; aquatic plants, night soil available (approximate).	These data can be collected from a few sample regions of the country and later extrapolated to get the national estimates.
	4. How much biogas will be produced from these sources ?	"	- biogas production when used separate or as a mixture.	
	5. What proportion of fuel needs it can meet ?		- quantity of commercial/traditional fuels used; - types of these sources and area of use; - proportion of fuel needs each of these meet; - source of commercial fuels; their price, availability; - proven and probable sources of commercial energy sources, if any.	
	6. What proportion of fertiliser needs it can meet ?	"	- quantity of dung currently used as fuel/fertiliser; - quantity of chemical fertilisers needed/produced; - per capita total energy fertiliser use (current and future)	

Decision making Stages	Major Decisions to be Made	Types of Information	Specific categories of Information Needed	Remarks
BT potential in the country (contd.)	7. Can the products of BT be used in the nation ?		- quantity of biogas likely to be produced; - quantity of sludge likely to be produced; - probable areas of use of biogas (cooking/lighting/running engines etc.); - types of use of sludge (crops responsive to sludge/quantity of sludge needed/mode of use of sludge for crops/use of sludge in aquaculture etc.); - proportion of total energy/fertiliser need that can be met by biogas sludge; - value of energy/fertiliser substituted by BT; - value of producing equivalent quantity of energy/fertiliser from existing sources.	
BT potential in the country	8. Does the nation have adequate construction materials for biogas plants ?	Natural resources, Economic	- deposits of lime, stone, gravel, etc.; - price and availability of construction materials; - rate of use of these materials for building construction.	

Decision making Stages	Major Decisions to be Made	Types of Information	Specific categories of Information Needed	Remarks
BT potential in the country (contd.)	9. Will BT improve rural sanitation and waste disposal problems ?	Socioeconomic	- how is the rural sanitation condition ? - how is the waste disposed generally ? - problems associated with waste disposal.	
	10. What would be the impact of BT in cattle population ?	Economic	- future cattle population if any; - increase in cattle population if any; - sources of fodder for population.	
	11. What would be the impact of BT on land, (agric/pasture) forests ?		- rate of deforestation; - rate of use of firewood for cooking; - pasture land necessary for the cattle population.	
	12. Are the geographical characteristics of the nation favourable for BT adoption ?	Geographical	- soil stability, spots vulnerable to soil erosion; - water table of sub-soil; - area marked by presence of rocks etc.; - location of the region; - average annual rainfall, etc.	

Decision making Stages	Major Decisions to be Made	Types of Information	Specific categories of Information Needed	Remarks
BT potential in the country (contd.)	13. Do the climatic conditions permit BT adoption ?	Meteorological	- climatic changes, temperature variation in a season; - different seasons over the country.	
	14. Are the auxiliary facilities of rural areas OK for introducing BT ?	Infrastructural	- the number of rural areas connected by bus/trains or other transport facilities; - the number of households getting pipe water/well water/river water etc.; - number of households having water source; - the number of shops/repair centres etc. in rural areas etc.	
	15. What will be the impact of BT on the people ?	Social, Religious	- readiness to use biogas cooking/lighting devices; - readiness to use biogas from night soil as one of the input; - willingness to use toilets; - willingness to connect toilets to BT plants.	
	16. What are the on-going and proposed energy and fertiliser projects ?	Economic	- current and proposed energy projects: their type, capacity, number of plants, regions where they are installed.	

Decision making Stages	Major Decisions to be Made	Types of Information	Specific categories of Information Needed	Remarks
BT potential in the country (contd.	17. What is the source/ mix of sources of energy best suited to the country ? 18. What is the source/ mix of sources of fertiliser best suited to the country ? 19. What is the priority attached to BT in this energy/fertiliser mix ?	Economic	- number of Fristing and proposed fertiliser projects; - number of fertilisers, plants, capacity location; - cost benefit study of each of the resources (individually and as groups); - capacity of each of these to meet the future need for fuel/ fertilisers, energy , - energy mix proposed, priority given to BT in this mix - fertiliser projects priority given to BT in this, etc.	-
III. National capacity for BT development	20. Does the nation have / can it develop the resources/facilities necessary for promoting BT ?	Institutional	- institutions/organisations capable of planning and implementing the programme; - institutions capable of carrying out R&D training; - institutions/agencies involved in extension work/rural development activities etc.	

Decision making Stages	Major Decisions to be Made	Types of Information	Specific categories of Information Needed	Remarks
National capacity for BT development	Does the nation have/can it develop the resources/facilities necessary for promoting BT ?	Technological	- status of ongoing BT activities in the country; - capacity of the nation to develop appropriate plant models and devices etc.	
		Economic	- human resources potential of the country for promoting BT; - economic status of the people.	At the policy formulation stage, it is sufficient to have a qualitative evaluation of all the aspects mentioned in the 3 stages.
		Financial	- amount required for promoting BT; - sources of finance (local/regional/national/international etc.); - means of recovering the financial assistance offered etc.	
	21. What is the status of BT activities ?	Technological	- number of BT plants operational/not functioning;	This information is collected from the existing plant sites. To be used to evaluate the feasibility of existing plant model, type, etc.
	22. Is the current state of affairs satisfactory ?	Economic	- reasons for abandoning the plants;	
	23. Is the failure due to technological incapability or geographical, or other reasons ?		geographical climatic and other characteristics of the plant site;	The specific categories of information for this study are as given in Stage II.

Decision making Stages	Major Decisions to be Made	Types of Information	Specific categories of Information Needed	Remarks
			- institutional/human and other resources in relation to BT.	

IV. BT Development Target Fixing	24. What proportion of energy need should biogas substitute ?	Economic	- experience of the country with BT;
			- quantity of biogas that can be produced from the organic wastes available;
			- other uses of input materials (cattle/fodder);
			- quantity of input materials available for use in BT
			  - efficiency of collection of input materials;
			  - possibility of using night soil as input and to which extent;
			- priority attached to BT among the energy projects of the nation;
				These decisions are to be supported by adequate-data on the energy/fertiliser requirements of the nation, potential of BT in the country and the capability of the nation to support the programme. As such it relates to the previous 3 stages of decision making.

	25. What proportion of fertiliser need the sludge should meet ?	Technological	- quantity of sludge likely to be produced; - fertiliser content of the sludge; - possible modes of use of sludge;	

Decision making Stages	Major Decisions to be Made	Types of Information	Specific categories of Information Needed	Remarks
BT Development Target Fixing (contd.)			- quantity of dung and other wastes likely to be used for composting.	
		Economic	- existing/proposed chemical fertiliser projects of the nation; - priority assigned to BT among the fertiliser projects.	
	26. How many biogas plants are to be built in a specific period ?	Financial	- financial resources available for the period.	
		Socio-cultural	- degree of acceptance of BT by the people.	
		Economic	- intensity of diffusion/extension activities intended etc.	
	27. In which areas should BT be initiated ?	Economic	- regions/states/other administrative divisions of the country; - per capita income of these regions; - educational status of the people in these regions; - input materials availability; - availability of other facilities.	The objective is to initiate the programme in certain areas where conditions are favourable for BT adoption. However this does not imply programme initiation in an area seemingly less suited for initiation but where voluntary organisations or other agencies are willing to popularise it.
		Geographical	- geographic peculiarities of the region.	
		Climatological	- climatic characteristics.	

Decision making Stages	Major Decisions to be Made	Types of Information	Specific categories of Information Needed	Remarks
BT Development Target Fixing (contd.)		Social	- assumed rate of acceptance of the technology by people.	
	28. Should the technology be oriented to any particular strate of the people ?	Economic	- relationship between economic status and energy/fertiliser consumption pattern in the region; - occupational pattern of the region; - type of economy of the region; - degree of cooperation among the people; - quantity of traditional fuels available.	
		Financial	- capacity of the people to repay the amount advanced; - capacity of the nation to partially/completely finance biogas plants of the poor people.	
	29. What are the facilities to be provided for BT development and promotion ?	Financial	- Financial incentives for manufacturers of plant parts/utilisation - devices; small scale industrial units for purchase of machines using biogas;	This draws upon all the information on the resources and demand for BT collected in Stage 2.

Decision making Stages	Major Decisions to be Made	Types of Information	Specific categories of Information Needed	Remarks
BT Development Target Fixing (contd.)		Technological	- number of R&D projects to be promoted and the financial/material/human resources facilities for each.	
		Human resources development	- facilities for human resources development for extension;	
		Financial	- facilities to be provided to the beneficiaries (subsidy/loan for plant construction, purchase of devices, etc.).	
		Economic	- facilities for marketing of products if necessary.	
	30. How to make maximum use of BT ?	Technological	- selection of the plant model and type appropriate for the nation/region; - education of beneficiaries on operation of biogas plants.	
		Economic	- facilities to be provided to the rural areas for repair of plant parts/devices;	

Decision making Stages	Major Decisions to be Made	Types of Information	Specific categories of Information Needed	Remarks
BT Development Target Fixing (contd.)			- facilities for providing continued technical advice and support to the beneficiaries (extension workers/other development functionaries to visit the plants periodically and on request from beneficiaries.	
		Administrative	- guidelines for flow of information from the beneficiaries/entrepreneurs to the R&D personnel and vise versa;	
			- provision for motivating the grass-root level workers (adequate salary and proper service conditions etc.).	
	31. Should BT development programme be phased out ?		- capacity of the nation to finance the programme;	
			- manpower availability;	
			- availability of other facilities (materials);	
			- receptiveness and enthusiasm of the people towards BT;	

Decision making Stages	Major Decisions to be Made	Types of Information	Specific categories of Information Needed	Remarks
			- duration of the programme; - activities to be carried out in different phases.	
V. R&D planning	32. Does the country have adequate technological know-how ?	Technological Socioeconomic	- technological know-how available; - is the existing technology viable ? - number of BT R&D institution; - biogas expertise available; - BT equipments/ devices available and their viability;	This exercise is done partly at the Stage III.
	33. Should the technology be borrowed ?	Economic, political	- source, methodology, medality for transferring the technology.	
	34. Which is the plant design appropriate to the country ?	Technological	- modifications to be done for the borrowed existing/ design, utilisation devices, etc.	
	35. How to orient BT R&D to the current and future needs of the country ?	Financial R&D management	- specific areas of R&D work needed for the country; - financial allocation for BT R&D (areas of assistance, norms amount);	
	36. What should be the policy regarding R&D financing ?			

Decision making Stages	Major Decisions to be Made	Types of Information	Specific categories of Information Needed	Remarks
	37. How to plan R&D monitoring ?		- agency for R&D financing; - research areas to be financed, - areas of R&D monitoring; - agency for R&D monitoring.	
VI. Diffusion planning	38. In which area BT extension work can be initiated ?	Economic Geographical Meteorological Technological	- population served; - geographical climatological and other conditions of the area; - input availability, variety; - availability of other resources like construction materials, water, etc.; - potential of the area for economic development; - energy consumption pattern; - possibility of Integrated Biogas System.	This can be under the priority areas selected in Stage IV
	39. What are the facilities to be provided to these areas ?	Economic	- construction materials and facilities, water, financial resources etc.	

Decision making Stages	Major Decisions to be Made	Types of Information	Specific categories of Information Needed	Remarks
Diffusion Planning (contd.)	40. What would be the total financial commitment for demonstration ?	Financial	- number of demonstration plants to be constructed; - approximate expenditure per plant; - local financial sources if any.	
	41. What would be the probable expenditure for large scale adoption ?	Financial	- number of plants likely to be constructed; - possible areas of assistance (plant construction/utilisation devices/engines, setting up factories/workshops for production/repair of plant parts and utilisation devices. - average expenditure per plant.	
	42. What are the norms for giving financial assistance ?	Financial	- eligibility criteria for financial assistance; - possession of land; - number of cattlehead possessed; - income of the family; - purpose of loan; - conditions for repayment; - rate of interest; - payback period; - upper and lower limits of money paid per month etc.	The norms may be fixed by the National Financing Agency or the National Agency for BT development.

Decision making Stages	Major Decisions to be Made	Types of Information	Specific categories of Information Needed	Remarks
VII. Manpower planning	43. What are the manpower requirements of BT development ?	Administrative	- number of units/agencies; - number of staff in each - salary, job requirements etc.; - number of field staff necessary (extension workers); - number of skilled construction; workers - number of workers needed.	
	44. How to fulfil the manpower requirements ?	Administrative	- existing institutes for training, R&D etc.; - performance rate: number of people trained - expertise available etc. in these institutes;	
	45. How good are the existing training facilities ?		- number of institutes to be set up for training; - number and category of people to be trained.	
	46. What are the norms for training ?	Administrative	- qualification for selection as extension workers, construction workers; - course curriculum, duration; - methods for deployment of the trainees.	

Decision making Stages	Major Decisions to be Made	Types of Information	Specific categories of Information Needed	Remarks
Financial Planning (contd.)	49. What would be the financial implication of these ?	Financial	- approximate expenditure in each of these; - aggregate; - modes of reducing costs if any;	
	50. What are the norms for giving financial assistance ?	Economic	- forms of assistance (subsidy/grant/loan etc.); - areas of assistance (R&D, manpower, extension); - modalities for recovering a portion of the amount.	This information is necessary for BT diffusion also.
	51. What are the sources for getting the necessary finance ?	Economic	- sources of finance, national/international assistance.	This is the aggregate result of all similar steps in previous stages.

Decision making Stages	Major Decisions to be Made	Types of Information	Specific categories of Information Needed	Remarks
Manpower Planning (contd.)		Financial	- financial expenditure per student.	
		Administrative	- duration, frequency of orientation programmes; - number and type of BT development functionaries for the programme.	

	47. Should the training be financed by the Government ?	Financial	- norms for financing;
			- expenditure for the same;
			- sources of finance
			  - Government
			  - Other sources.	

VIII. Financial planning	48. Which are the areas to be financed ?	Financial	- assistance to R&D; - assistance to training of extension and construction workers; - financing demonstration plants; - assistance to beneficiaries (plant construction, equipments etc.); - expenditure in other areas (administration, supervision, infrastructural development etc.)	Obtained from calculations of finance in all the previous stages.

ANNEXURE 4

Fact Sheet of Training Course for Biogas Technology Extension Workers

1. Objective

To create a cadre of BT extension workers for diffusing the technology among the people.

The focus will be on a detailed study of the technology as well as the various techniques for its extension.

2. Participants

The participants for this course can be selected from among voluntary organisations or agricultural extension workers or rural development workers etc. Young people with a minimum of secondary education and interest and aptitude in BT extension may also be considered.

3. Medium of Instruction

English/National Language/Vernacular

4. Syllabus

Suggested topics include :

a) Theory

- What is BT ?
- Principles, reactions, agents etc. of BT;
- Descriptions of different plant models;
- Selection of model, size and site of plants;
- Calculation of input materials to be added;
- Construction details of plants;
- Operation and maintenance;
- Uses of biogas and the sludge;
- Availability, operation, maintenance etc. of utilisation devices.

b) Application

- Need for BT extension;
- Techniques of BT extension: Methods of collecting data, methods for dissemination like formal and informal discussions lectures, slide-shows etc., language and standard of communication with the people etc.;

- Case studies of BT extension in a few nations/regions;
- Financing: Institutional credit support for BT financing, modalities and time tables for getting the assistance;
- Infrastructural development: Agencies for production/distribution/service of plant parts and utilisation devices, guidelines for setting up small industry units, techniques of entrepreneurial development, institutes/agencies imparting construction training, information on course offered etc.;
- Project monitoring: Methods of collection of plant performance data, analysis of data, cost-benefit study etc.;
- Report writing.

c) Practical

- Observation of plant construction works;
- Visits to agencies fabricating plant parts, utilisation devices etc.

5. Duration

4 weeks including 1 week observation of an existing biogas plant.

6. Venue

Regional/national centres. These could be attached to the existing agricultural extension or social service centres or to the BT R&D institutes.

7. Faculty for Training

Faculty should consist of BT R&D personnel, economists, etc. with adequate practical experience in working in a village situation.

8. Progress Report

The training centre should furnish the following information to the regional authority for BT development

- Names and addresses of people trained as extension workers;
- Number of persons taken from voluntary organisation, agricultural extension units, etc.;
- Actual expenditure involved.

9. Monitoring and follow up

The regional authority will be responsible for coordination and supervision of the course.

10. <u>Funds</u>

Funds should be provided by the national agency for BT development for the following items for each course :

- Stipend
- Transportation and stationery charges
- Charges of study tour
- Honorarium to the faculty, etc.

ANNEXURE 5

Construction Training Course for Village Masons: Fact Sheet

1. **Objective**

To create a large cadre of village masons trained in the construction and maintenance of biogas units.

Focus will be on intensive practical training so that the trainees are equipped with the skill of actual construction of a biogas unit.

2. **Participants**

The course is intended for professional masons only.

3. **Medium of instruction**

Preferably in vernacular language.

4. **Syllabus**

Suggested topics/items are as under :

a) **Theory:** (May be restricted to one-two days only)

- What is biogas ?
- Biogas production technology.
- Description of plant design.
- Selection of site, suitable size of plant, etc.
- Requirement of materials.
- Construction details.
- Laying of pipe line.
- Operation and maintenance of biogas plant.
- Use of biogas.
- Use of digested slurry.
- Central subsidy pattern.
- Loaning facilities.
- Use of biogas for running of diesel engine.
- Use of digested slurry for raising crops and vegetables.

b) Practical:

- Selection of site, levelling, demarcation.
- Digging work.
- Foundation.
- Construction of digestor wall and openings for inlet and outlet chambers.
- Form work and shuttering
- Casting of dome.
- Construction of inlet and outlet chambers.
- Construction of dung mixing tank.
- Curing of dome.
- Removing of shuttering.
- Groove cutting.
- Dome plastering and finishing.
- Digestor and inlet and outlet chambers plastering and finishing.
- Floor plastering and finishing.
- Filling of earth on top of dome and in side walls.
- Laying of pipe line.
- Fixing of water removal, gas burner lamp.
- Preparation of dung slurry.
- Feeding the digestor.
- Operation and maintenance of biogas plant.
- Testing of gas-leak proofness.
- Attachment of latrine.

5. Duration

3-4 weeks.

6. Suggested Venue

These courses should be organised at the district and wherever possible, at block levels.

7. Faculty for Training

Faculty for organising construction training should include trained master masons. The following arrangements should be utilised for drawing faculties for these courses :

A list of institutions which have developed expertise for imparting construction training to develop the trained master masons would have been identified. Initially these institutes may be those carrying out BT R&D.

A country getting BT know-how from another has to take measures to develop the construction skills necessary for the model alongwith its adoption.

The master masons thus trained are to be deployed to the different training centres.

8. Progress report

The regional body for BT development is required to furnish the following information :

a) Name and addresses of the masons trained and their evaluation into the the following categories :

(i) Masons who have acquired the skill to construct biogas units independently;

(ii) Assistant masons who will require casual supervision of master masons during the construction of biogas units;

b) Actual expenditure incurred.

9. Monitoring and follow-up

The regional body will be responsible for coordination and supervision of the construction training activities in the region. The individual training centres will report to the regional authority.

10. Funds

The course will have to be financed by the national body. The number of masons to be trained in each course and the number of courses to be conducted each year will be dictated by the demand for alternative and the potential of the region for development of BT.

Financial allocation per student should consider the following aspects :

- Stipend per student;
- Transport charges, stationery, etc.;
- Cost of constructing a biogas plant per student for their practical training;
- Honorarium, etc.

ANNEXURE 6

Orientation Programme: Fact Sheet

1. Objective

To make the development functionaries at various levels understand the benefits of BT and the implications of its execution and thus to elicit their cooperation and support.

2. Participants

The different types of development functionaries connected with BT development, e.g. local/regional agricultural officers, representatives of banks, rural development authorities, local/regional administrators like district collectors, members of the institutions/agencies concerned with BT development, universities, etc.

3. Medium of instruction

English/National language.

4. Course content

1. Theory (1-2 sessions can be devoted to this)
   - What is BT ?
   - Principles, processes, agents, plant models, etc.
   - Potential of BT in the national fuel/fertiliser scene.
   - Need for BT propagation.
   - Current trend of BT research and extension.
2. Implications
   - Plans and policies in relation to BT development.
   - Implications of these plans on the region in question (social, economic).
   - Financial implications of the programme.
   - Modalities for giving financial assistance.
   - Experiences in other regions if any.
   - Strategy to be followed for the region.

5. Duration

2 days.

6. Venue

Regional administrative headquarters, or BT research institutions.

7. Agency

The programme has to be organised by the regional agency for BT development. The programme coordinators should consist of planners, economists, social workers, etc.

8. Funds

The programme can be financed by the regional/national agency for BT development.

Annexure 7

Decision Making Points and Their Information Requirements at the Microlevel

Stages	Major decisions to be taken	Types of information needed	Specific category of information	Comments
Resources and Demand Assessment	1. How much of the BT input material the area has got ?	Economic Technological	As in decisions 1-4 of Stage II in national level planning.	The specific categories of information needed in this stage at the national, regional or local level will be the same, but here, the scope of study is limited to the geographical/administrative area taken as a unit for BT implementation.
	2. How much biogas can be produced from this ?		"	
	3. What proportion of fuel needs of the area it will meet ?		"	
	4. What proportion of fertilizer needs BT can meet ?	Economic Socio-economic		
	5. Will BT make the area self-sufficient in energy and fertilizer ?	Economic	- type and quantity of fuel sources currently purchased from outside the area; - chemical fertiliser purchased; (quantity) - potential of BT to substitute these fuel and fertiliser purchased.	
	6. How will BT help in the sanitation and waste disposal ?	Environmental, Cultural, Socio-economic	- number of cattlesheds that can be connected to biogas plant;	

Stages	Major decisions to be taken	Types of information needed	Specific category of information	Comments
Resources and Demand Assessment (contd.)			- number of toilets to be constructed and connected to biogas plant; - possibility of safe, uncontaminated drinking water; - possibility of environmental cleanliness in the area.	
	7. What would be the impact of BT on cattle population ?	Economic Social	- rate of growth of cattle population; - stabling habits of cattle; - increase in demand of fodder.	
	8. What would be the impact of BT on land pattern ?	Economic	- possible reduction in the use of firewood for cooking; - reduction in the rate of deforestation; - changes likely in the ratio between pasture land and cultivated land; - optimum ratio for the above.	
	9. Does the area have any of the construction materials for biogas plants ?	Natural resources Economic	- local deposits of clay, lime stone, gravel etc. - quantity of these materials used for building construction;	

Stages	Major decisions to be taken	Types of information needed	Specific category of information	Comments
Resources and Demand Assessment (contd.)			- local price of these materials if any; - availability and price of other materials like steel, galvanised iron etc.; - rate of use of these for building construction.	
	10. What other facilities the area has ?	Economic, Educational, Social	- transportation facilities in the area; - literacy of the people; - degree of receptiveness of the people in the case of other innovation; - drinking water availability; - irrigation facility; - nearness to the town.	
	11. What will be the villager's reaction to BT ?	Social Cultural Economic	- existing social practices, habits etc.; - major religions of the area; - social power structure in the area; - cultural practices; - educational status; - income distribution; - degree of receptiveness to innovations.	

Stages	Major decisions to be taken	Types of information needed	Specific category of information	Comments
Choice of energy sources	12. What is the energy mix suited to the area ?	Economic	- current energy use pattern (by types of energy and areas of use); - current fertiliser use pattern; - availability of these sources; - price; - number of households using petroleum fuels; - number of households electrified; - future programmes for electrification of the area; - number of farms using machines for agricultural operations; - number of households possessing minimum number of cattleheads for biogas plant; - number of households not possessing cattle; - number of households using dried dung as fuel, but not possessing cattle; - proportion (current and intended) of energy/fertiliser demand served by each of these sources;	

Stages	Major decisions to be taken	Types of information needed	Specific category of information	Comments
			economics of using the above sources individually or as a mix.	

Choice of the appropriate plant model and type	13. Is the plant model selected at national/regional level appropriate to the area ?	Technological
		Economic
		Geographical
		Climatological
			- characteristics of the model;
			- input materials available and necessary;
			- soil stability;
			- degree of water table;
			- hard rocks if any;
			- average temperature (per season/annual);
			- rainfall of the area;
			- intended use of outputs;
			  - preference for biogas or
			  - preference for fertiliser.	

	14. Which type/types of plants is suited for the area ?	Economic	- number of households possessing the required minimum of input sources; - distribution of households according to possession of inputs; - income distribution among those households; - number of households using dried dung and possessing cattle; - number of households using dried dung but not possessing cattle,	

Stages	Major decisions to be taken	Types of information needed	Specific category of information	Comments
Choice of the appropriate plant model and type (contd.)		Social	- willingness of the villagers/households to cooperate; - possibility of arranging dung supply from households possessing below minimum cattlehead; - possibility of supplying fuel to the poor people.	
		Economic	- number and types of rural industries; - energy requirements of these industries; - possibility of using biogas in these industries/operations; - price and collection mechanism of dung from participating households.	
		Managerial	- distribution of output - spatial contiguity of participating households.	

	15. What are the facilities to be given to the local level beneficiaries ?	Technological
		Managerial
			- price of output
			  - market price of dung and other fuel sources;
			  - price of chemical fertilisers;
			- mechanism to ensure sustained operation of the plant;
				Given in detail in Individual Level. This needs additional information on the operational scheme for community plant. which is decided upon the social,

Stages	Major decisions to be taken	Types of information needed	Specific category of information	Comments
			- guidance to the family plant owner; - guidance to the authorities of community plants; - intended role of these households.	economic and managerial decisions given above.
BT adoption in the area	16. What are the infra-structural/facilities needed for the area ?	Entrepreneurial development, Information on Equipments	- number of shops where plant parts/utilisation devices are available; - number of workshops for repair/maintenance of plants/equipments;	
		Manpower information	- provision for construction materials; - construction workers needed; - other skilled/semi-skilled labourers if necessary; - selection, recommendation of people for training in the above field.	
		Financial	- arrangements for using concessions/subsidies in construction materials, plant construction, manufacture of equipments, etc.;	

Stages	Major decisions to be taken	Types of information needed	Specific category of information	Comments
			- establishing liaision between the local financing unit and the people.	
Financial Provision	17. What would be the expenditure of plants in the area ?	Financial	- number and cost of the demonstration plant in the area; - number of plants likely to be constructed; - expenditure for each; - expenditure for demons-tration plants; - expenditure for other items.	

Annexure 8

Biogas Plant for a 6 member family - Illustration

A hypothetical household situation consisting of 6 members of the family and 5 cattlehead is given below to illustrate the decision making processes involved in adopting BT. The family intends to use the biogas produced for its cooking needs met so far by traditional fuel sources. The sludge is intended to be used in the field and also in the vegetable garden. *

Assumptions

a) 10 kg of dung is collected/day/cattle at the rate of approximately 70% dung collection efficiency.
b) 200 g (or 200 ml) of flush water and 800 ml of urine available per person with 1 litre.
c) 28 kg of dung produces 1 m^3 of biogas in 50 days at 27°C.
d) Nitrogen content of the sludge is 1.2% of the dry matter.
e) 1.5 m^3 of gas is required for cooking 3 meals for a family of 6 people.
f) The family is using the cattle dung for composting (prior to adoption of BT).
g) The model proposed is Indian design (vertical model).

For convenience, the decision making activities in this level are grouped into the following 3 main divisions :

a) Decision for plant installation;
b) Plant installation, operation and use;
c) Activities/decisions associated with realising financial assistance offered.

---

* Source: Patel, SM. Performance of Biogas Plants in Gujarat. - Khadi Gramodyog, Aug. 1975; 493-502.

Annexure 8a

Decision for-Plant Installation

Decisions to be made	Types of information required	Calculations	Results/Comments
1. Is the model recommended appropriate to the household ?	- inpu. materials available (type, quantity)	- cattle dung from 5 cows. The toilet can be connected to the plant. Thus on an average 50 kg of dung and 6 kg of human excreta will be available per day.	
	- possibility of using them together in the model	- yes. Both cattle dung and night soil can be used.	
	- quantity and type of construction materials needed for the model	- masonry materials and mild steel. A minimum of 35 kg cement would be necessary.	
	- soil characteristics of the compound	- no rocks. The compound of the household has a low water table.	The model can be accepted.
2. Are there any modifications to be made to the model ?	- precautions to be taken in winter	- no severe winter, and the temperature fluctuations are not very high	
	- intended use of outputs	- mainly for domestic use of the biogas produced especially for cooking and lighting.	

Decisions to be made	Types of information required	Calculations	Results/Comments
-	- modifications to suit any or all of the above characteristics	- no.	The model can be accepted without modification.
3. What would be the size of the plant ?	- efficiency of dung collection expected	- the cows will be grazing in fields during daytime. Hence efficiency expected is 2/3 of the dung produced/ day. The average quantity of dung produced per cattle per day is assumed to be 15 kg.	
	- quantity and type of input materials available, and the volume of slurry	- 50 kg of dung available per day. The human excreta and urine will come to about 1 litre/ person and thus a total of 56 kg (1 kg = 1 litre). The volume of slurry per day would be 56 + 56 = 112 litres.	
	- likely increase in the above in the near future	- no. It will be more or less stable.	
	- type of use of biogas intended	- cooking of meals 3 times a day. If available, the extra gas can be used for lighting. There are 6 points of lighting in the house which will burn approximately for 5 hrs/day.	

Decisions to be made	Types of information required	Calculations	Results/Comments
what would be the size of the plant ? (contd.)	- quantity of biogas required	- 1.5 m^3 of biogas for cooking and 4.3 m^3 for lighting.	
	- possible increase in biogas use in the near future	- no. Intended only for cooking and lighting.	
	- types of use sludge intended	- to be used as fertiliser in the vegetable garden and rice fields alongwith irrigation water.	
	- expected increase in fertiliser demand	- nil.	
	- quantity of construction materials available	- cement, bricks, mild steel etc. can be procured.	
	- what should be the volume of the digester and the gas holder ?	- the volume of the digester should be 112 x 50 (50 days retention period) = 5.6 m^3. The gas holder should be able to hold approximately 2/3 of the gas produced at a time.	
	- how much biogas will be produced per day ?	- approximately 3 m (or 105 Cu. ft.) of biogas per day.	
	- is there enough space in the compound for the plant ?	- yes.	

Decisions to be made	Types of information required	Calculations	Results/Comments
	- is there regular source of water nearby ?	- yes, it is in the same compound as the plant; and 56 litres of water can be used daily for the plant.	Since there is no likelihood of increase in the supply of input materials or the demand for biogas or sludge, the optimum size of the plant is 3 m^3 in terms of the volume of gas produced/day.
Can the household owner afford the initial cost of plant installation ?	- size of the plant	- 3 m^3 of biogas/day.	
	- approximate cost of installation including that of construction materials and labour cost	- approximately Rs. 3,000/-;	
	- expenditure to be borne by the owner	- minimum 25% of the cost (according to financial assistance policy of the nation) i.e. around Rs. 750/-.	
	- amount the owner should possess before starting construction work	- at least 50% of the construction cost i.e. Rs. 1,500/-.	This is to overcome the possible delay in getting the amount sanctioned by way of assistance.
	- can he afford to spare this amount ?	- yes.	The household can go in for a biogas plant.
5. Do the social and cultural practices of the household members allow installing a biogas plant ?	- what is the housewife's reaction to cooking with biogas ?	- no objection. Has seen the benefit of biogas in the neighbourhood.	

Decisions to be made	Types of information required	Calculations	Results/Comments
	- what is their reaction to connecting toilets to plants ?	- no objection to use the biogas thus produced for cooking.	
	- is the reaction to handling slurry and sludge favourable ?	- yes. Any member of the family can prepare the slurry alongwith the daily cleaning of the cattleshed. The sludge is odourless and thus pose no problem in handling.	
	- are they willing to have biogas plant installed ?	- yes.	The household members are willing to have the biogas plant attached to household and hence can start work.

<u>NOTE</u> : Consequent to these decision making exercises, the household owner makes the final decision to proceed with biogas plant installation work.

Annexure 8b

Plant Installation and Operation

Decisions to be made	Types of information required	Calculations	Results/Remarks
1. Where should the plant be installed ?	- distance between the plant site and points of use	- near the kitchen	A place near the kitchen and cattleshed but away from well was selected. Septic tank can be connected to the plant without additional expenses.
	- distance between the plant site and source of input materials	- near the cattleshed	
	- distance from wells or other drinking water sources	- away from the well	
	- presence of big trees near the site	- no	
	- distance between the plant site and sludge storage pits	- not far	
2. Should the plant be constructed or parts to be brought ?	- availability of plant parts	- yes	Acquisition of prefabricated plant parts is not cost effective. Hence the plant has to be constructed on site.
	- price of the above	- too high	
	- distance from the source of production and facilities for transportation	- transportation cost will be very high	
3. How to organise/supervise construction work ?	- what are the construction materials to be purchased/prepared and how much ?	- cement, GI pipes, mild steel etc.	
	- are they of the right quality ?	- yes	
	- approximate price of these materials	- the price of these materials are to be taken out individually in actual practice, but here, only an approximation of the total cost of construction is given.	

Decisions to be made	Types of information required	Calculations	Results/Remarks
	- preconstruction checking of the site soil (structure, firmness)	- the ground is firm, the soil is not formed of clay, and the degree of water table is not high.	
	- labour availability	- skilled construction workers are available.	
	- duration of construction	- one week.	
	- construction of digester		
	- the volume, wall thickness of the digester	-	
	- height of the digester above the ground	- 22 cms	
	- backfilling work	- after building every 30 cms of the digester wall	
	- size, diameter, and other specifications of inlet/outlet tanks, inlet/outlet pipes, deflector ledge, central guide etc.		
	· size, pressure regulation, height and other considerations for gas holder	- height is 1.2 m. The gas holder is painted before fitting with the digester	Organisation and supervision of plant construction work can be undertaken.
	- checking for digester cracks, leaks etc.	- nil	

Decisions to be made	Types of information required	Calculations	Results/Remarks
4. What are the methods to ensure a steady operation of the plant ?	- pretreatment of the digester	- not required	
	- correct way of slurry preparation	- dung and water mixed in 1:1 ratio to make a uniform solution	
	- is the dung adequate for 1st filling ?	- yes	
	- frequency of slurry feeding	- after 1 gas holder full of gas has been removed, the slurry is fed daily.	
	- precautions against scum formation	- the gas holder can be rotated once a day or so to break the scum	
	- are the utilisation devices functioning well ?		
	- gas pressure in the stove	- the burner should give a a blue flame	
	- gas pressure in other points of use		
	- minor operational snags and their remedy	- can be done by the plant owner himself	- The plant owner is adequately informed about plant operation.
	- periodicity of plant parts maintenance/replacement	- gas holder to be painted once a year	
	- average life expectancy of the plant	20 years for digester 8 years for the gas holder	

Decisions to be made	Types of information required	Calculations	Results/Remarks
5. Should the utilisation devices be bought or fabricated indegenously ?	- intended types of use	- for cooking the additional gas produced can be used to light 2 points	
	- types of devices needed	- i. e. 1 cooking stove and 2 biogas lamps are needed	
	- their availability	- available in the market	
	- price	- Rs. 250/- (this is given only as an example)	
	- knowledge of converting an existing device to suit use of biogas	- the household owner does not possess the required knowledge	
	- efficiency of such devices	- may be efficient, but without adequate knowledge better not risk it	The utilisation devices can be purchased from the market.
	- cost effectiveness of converting such devices	- may not be cost effective	
6. What are the uses to be made of biogas ?	- types of use intended	- cooking 3 meals/day plus making coffee/tea twice, lighting	
	- points of use	- 1 in the kitchen and 6 lighting points	

Decisions to be made	Types of information required	Calculations	Results/Remarks
What are the uses to be made of biogas ? (contd.)	- quantity of biogas needed	- 1.5 m^3 for cooking 4.2 m^3 for lighting, but the gas produced is only 3 m^3. So 1.5 m^3 can be used for cooking and the rest 1.5 m^3 is sufficient to light 2 lamps for 5 hrs a day	
	- frequency of use of the biogas	- irregular	
	- handling methods of stoves/lamps	- can be handled	Biogas produced can supply the cooking fuel and supplement the lighting fuel needs of the household.
	- should other fuels be purchased ? If so, how much ?	- yes, for lighting and all other fuel needs of the household	
7. What are the uses to be made of sludge ?	- quantity of sludge	- about 70% of the total solids in slurry comes out as sludge	
	- types of crops for which sludge can be applied	- vegetable, rice	
	- appropriate time for applying the sludge	- twice a week to the vegetable garden and according to sowing and cropping season in the rice fields	

Decisions to be made	Types of information needed	Calculations	Results/Remarks
	- mode of application	- liquid form (preferably) carried by irrigation water	The sludge can meet partial fertiliser requirements of the household.
	- other types of fertiliser to be bought	- certain quantity of fertiliser will have to be brought	
8. Should biogas be used as such or converted to electricity ?	- types of use intended	- cooking lighting	
	- do the areas of use demand conversion ?	- lighting	
	- availability of conversion engines	- yes	
	- price	- highly expensive for a household	Biogas can be used as such, conversion is not cost-effective.
	- cost benefit study of the 2 alternatives	- using as biogas as such is cost beneficial	

Annexure 8c

Realising Financial Assistance

Decisions to be made	Types of information required	Calculations	Results/Remarks
1. What is the expenditure likely to be incurred ?	- approximate cost of construction	- Rs. 3,000/-	
2. Which is the source for financial assistance ?	- agency offering assistance	- local branch of Bank	The local branch of Bank 'X' can give upto 75% of the cost of construction
	- type and amount of such assistance	- as loan. 75% of the cost of construction (i. e. Rs. 2,250/-)	
	- purpose for which it is necessary	- construction	
3. Is the plant owner eligible for assistance ?	- norms for getting assistance	- the farmers were told of these	
	- minimum number of cattle heads needed	- qualified for loan	
	- landed property needed	- - do -	
	- income limit	- - do -	
	- amount to be spent by the household owner	- Rs. 750/- (25%)	
	- period of repayment of loan	- in few years time	
	- interest rate	- 12%	The household is eligible for financial assistance and can afford to spend the rest 25% of the cost of construction. The
	- amount to be paid per instalment	- nominal	
	- amount available as subsidy/grant etc.	- nil	amount of loan will be paid in easy instalments.

Decisions to be made	Types of information required	Calculations	Results/Remarks
4. Is the adoption of BT cost effective ?	- capital cost for plant installation	- Rs. 3,000/-	
	- depreciation and maintenance cost	- Rs. 300/-	
	- interest to be paid to the loan	- 12%	
	- cost of labour for operation	- Rs. 35/-	
	- volume of biogas generated	- 3 m^3/day	
	- effective heat obtained	- 8662.5 kcal (1 cu.ft. of biogas has 82.5 kcal)	
	- value of biogas produced in relation to other fuels	- 105 cu.ft. (3 m of biogas is equivalent to 2 litres of kerosene	
	- volume of fertiliser produced	- 51 kg of input (50 kg wet dung and 1 kg of human excreta excluding urine) is assumed to be available/day - dry matter available = 10.2 kg/day (20% of wet dung) - loss of dry matter during fermentation (20%) is 2.04 kg/day - average dry matter in the sludge/day = 8.16 kg	